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### STUDIES ON ASIATIC RELATIVES OF MAIZE<sup>1</sup>

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#### INTRODUCTION

The five oriental genera of the Tripsaceae—*Coix*, *Trilobachne*, *Polytoca*, *Sclerachne* and *Chionachne*—are especially worthy of an investigation more detailed than has hitherto been accorded them, not only because of their close relationship to maize but in their own right. They form a series of primitive forage plants, grain crops, and weeds, concerning which very little, aside from taxonomic descriptions, has appeared in print. As thorough as the study of maize has been, it is not improbable that a better knowledge of its Old World relatives will go some way towards helping to solve the big problem it still presents, that of its origin.

*Coix* is a cereal so ancient that it is mentioned in Vedic literature, was cultivated by the Aryans on the hill-slopes of the Himalayas, and at the present day is an important food grain of some of the aboriginal tribes of India (Watt, 1904). Watt infers, judging by the amount of attention the plant received in early botanical writings such as those of Pliny, Rumphius, Loureiro, and Gerarde, that formerly it was more extensively cultivated. Wester (1920), however, believes that though the hard-shelled forms of *Coix* were known in Europe as far back as the time of Pliny, the soft-shelled kinds do not appear to have been known to European writers until the seventeenth century.

The Arabs are responsible for its introduction into Spain and thereby to the West in general, and also for the picturesque name by which it is commonly known in Europe, Job's Tears (Watt, 1904).

Though a small and well-defined genus it is made up of ill-defined and poorly understood taxa, largely because of the occurrence of numerous intergrading forms. Therefore, those who have worked on the genus (Watt, Vallaëys, and Mimeur) do not agree too closely about which taxa should be allotted specific rank. In Table I are listed in chronological order as many basonyms in the genus *Coix*, as

<sup>1</sup>An investigation carried out in the Henry Shaw School of Botany of Washington University and submitted as a thesis in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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TABLE I  
NOMENCLATURE IN THE GENUS *COIX*

	Watt	Vallaes	Mimeur
1. <i>C. Lacryma Jobi</i> L. Sp. Pl. 972. 1753.	1	----	1
2. <i>C. Lacryma Jobi</i> Thunb. Fl. Jap. 37. 1787.	1	----	----
3. <i>C. arundinacea</i> Lam. Encyc. Méthod. 3:422. 1789.	1	----	----
4. <i>C. agrestis</i> Lour. Fl. Coch. 2:551. 1790.	7?	----	----
4a. <i>C. Lacryma-Jobi</i> 1. <i>agrestis</i> (Lour.) Backer, Handb. Fl. Java 2:33. 1928.	----	4b	----
4b. <i>C. Lacryma-Jobi</i> forma <i>agrestis</i> (Lour.) [incorrectly attributed to Backer by] Vallaes in Bull. Agr. Congo Belge 39:255. 1948.	----	4b	----
5. <i>C. pendula</i> Salisb. Prod. 28. 1796.	1	----	----
6. <i>C. exaltata</i> Jacq. Eclog. Gram. 60. 1813-1820.	1	----	----
7. <i>C. gigantea</i> Koen. ex Roxb. Hort. Beng. 66. 1814.	7	----	7
7a. <i>C. Lacryma-Jobi</i> var. <i>gigantea</i> (Roxb.) Stapf ex Hook. Fl. Brit. Ind. 7:100. 1896.	7	----	----
8. <i>C. aquatica</i> Roxb. in Fl. Ind. 3:571. 1832.	8a	8c	8a
8a. <i>C. gigantea</i> Koen. ex Roxb. var. <i>aquatica</i> (Roxb.) Watt, Agr. Ledger 11:198. 1904.	8a	8c	8a
8b. <i>C. Lacryma-Jobi</i> 4. <i>aquatica</i> (Roxb.) Backer, Handbk. Fl. Java 2:33. 1928.	----	8c	----
8c. <i>C. Lacryma-Jobi</i> forma <i>aquatica</i> (Roxb.) [incorrectly attributed to Backer by] Vallaes, l.c. 1948.	----	8c	----
9. <i>C. chinensis</i> Tod. in Index Sem. Hort. Bot. Pan. [Palermo], 5. 1861.	10a	10b	----
10. <i>C. Ma-yuen</i> Roman. in Bull. Soc. Nat. Acclimat. II, 7:442-444. 1881.	10a	10b	----
10a. <i>C. Lacryma-Jobi</i> var. "Ma-yuen" (Roman.) Stapf ex Hook. Fl. Brit. Ind. 7:100. 1896.	10a	10b	10a
10b. <i>C. Lacryma-Jobi</i> forma "Ma-yuen" (Roman.) [incorrectly attributed to Stapf by] Vallaes, l.c. 254.	----	10b	----
11. <i>C. Lacryma</i> var. <i>stenocarpa</i> Oliver in Hook. Ic. Pl. III, 8: pl. 1764. 1888.	11	----	11
11a. <i>C. stenocarpa</i> (Oliver) Balansa in Jour. de Bot. [Paris] 4:77. 1890.	11	11b	----
11b. <i>C. Lacryma-Jobi</i> forma <i>stenocarpa</i> (Oliver) [incorrectly attributed to Stapf by] Vallaes, l.c. 255.	----	11b	----
12. <i>C. puellarum</i> Balansa, l.c.	15	----	----
13. <i>C.* tubulosa</i> Hack. ex Warb. in Bot. Jahrb. 13:260. 1891.	11	----	----
14. <i>C. lingulata</i> Hack. in Oest. Bot. Zeitschr. 41:5. 1891.	7	----	----
15. <i>C. Lacryma-Jobi</i> var. <i>monilifer</i> Watt, l.c. 214.	15	15a	15
15a. <i>C. Lacryma-Jobi</i> forma <i>monilifer</i> (Watt) [incorrectly attributed to Watt by] Vallaes, l.c. 254.	----	15a	----
16. <i>C. Lacryma-Jobi</i> var. <i>typica</i> Watt, l.c. 206.	16	----	16
17. <i>C. ouwebandii</i> Koord. in Bull. Jard. Bot. Buitenz. III, 1:191. 1918.	----	----	17
18. <i>C. palustris</i> Koord. l.c.	----	18b	----
18a. <i>C. Lacryma-Jobi</i> 3. <i>palustris</i> (Koord.) Backer, l.c.	----	18b	----
18b. <i>C. Lacryma-Jobi</i> forma <i>palustris</i> (Koord.) [incorrectly attributed to Backer by] Vallaes, l.c. 255.	----	18b	----
19. <i>C. pollanei</i> Mimeur in Rev. Internat. Bot. Appl. 31:199. 1951.	----	----	19
20. <i>C. lacryma-jobi</i> var. <i>major</i> Mimeur, l.c. 202.	----	----	20
21. <i>C. lacryma-jobi</i> var. <i>minor</i> Mimeur, l.c. 204.	----	----	21

\* Here spelled *Coyx*.

delimited here, as were found. These bear the unmodified numbers 1 to 21. The list includes also a selection from the many combinations which have been made in this genus. These follow their respective basonyms and bear the same number modified by a letter. A number occurring in a column under one of the names,

Watt, Vallaeys, or Mimeur, indicates that the corresponding author equates the opposite name to that bearing the number given.

The best-known and most widely spread species is *Coix Lacryma Jobi* L. Originally native to southern and eastern Asia, it has today virtually run wild throughout the tropical and warm temperate regions of the world. The other species have a comparatively narrow distribution. *C. gigantea* Koen. ex Roxb. is found chiefly in the eastern and central parts of India, in Ceylon, Burma, and in Japan. Its variety *aquatica* has been reported in Indochina, western and southern India, Burma, and Japan. *C. ouwehandii* Koord. is endemic to Sumatra. Another endemic species is the one set up by Mimeur, *C. poilanei*, found in Laos.

Vallaeys (1948) suggests the Malay Archipelago as the center of origin of *Coix*, taking into consideration the multiplicity of varieties present there, some of which are not found elsewhere in the wild state. According to Burkill (1935), "it seems early to have become a cereal of some importance in the hills of Indochina and southern China, and it is probable that the beginnings of the cultivated races should be sought for in that part of the world."

As an article of diet, *Coix* used to be known as being most important during times of famine, helping to tide over seasons when the rice crop failed. Its nutritive importance, however, has impressed many investigators, and of recent years it has been gaining in popularity as a cereal and has come to be more generally cultivated. Wester was responsible for popularizing it in the Philippines where it is known as *Adlay*. Since then similar campaigns have been set in motion in Java, Ceylon, the Belgian Congo, Guatemala, Nicaragua, Costa-Rica, Bolivia, Peru, Chile and Brazil.

Analyzed along with certain other famine foods, its energy value was found to be the highest of all those studied (Paton and Dunlop, quoted by Watt, 1904). Wester (1920) records the results of analysis of the *Bukidnon* form of *adlay* as closely approximating wheat in starch and protein content and exceeding it in fat. Comparing it with two other great cereals of the world, he says, "with a greater protein and fat content than either rice and corn it is a more complete human food than either of these cereals."

An idea of its productiveness is obtained from Pieris' statement (1936) that a crop of *adlay* from an acre of land will provide sufficient food for a family of four people for about one year. Duthie (1888), speaking of its value as a fodder, says it is largely eaten by cattle and reported to be very fattening.

Vallaeys (1948) writes of its curious use as "the object of practices and beliefs held in magic" and also of the preparation of a refreshing drink from the grain which acts as a diuretic and a depuratory. In hospitals in China it is said to form a good and cheap substitute for barley in the making of gruel. It is known to be used in the elimination of stones from the bladder (Burkill, 1935). A decoction of the roots is given to children as a vermifuge (Ridley, 1906).

It is best known, however, for its use for decorative purposes, in the making of bead-baskets, rosaries, and various articles of personal adornment. Seeds of the wild forms with the hard, lustrous shells are the ones thus employed, usually those

belonging to var. *stenocarpa*, which has elongated, cylindrical false fruits, and those of var. *typica*, with false fruits of the characteristic tear-drop shape.

This list of the uses of *Coix* could be appropriately closed with a quotation from Vallaeys. Wherever man has lived it is possible to discover vestiges of ancient cultures and of plants whose use is lost. Speaking of the regrettable tendency to limit the number of products useful as food, he writes, "Cette limitation, cette 'standardisation' ne peuvent être considérées comme un progrès. Voilà pourquoi dans certains pays, on regard la coix comme une 'solution' à des problèmes d'importance capitale d'ordre diététique, économique et social".

Both *Polytoca* and *Chionachne* are generic names which owe their origin to Robert Brown (Bennett, Horsfield & Brown, 1838). Many species have been described for both genera as a result of which the literature has become cluttered with synonyms. In "A contribution to the knowledge of the Indian Maydeae" (1931), Henrard made an attempt to clarify their taxonomy.

The following table is based on Henrard's and Pilger's treatments. It is constructed in the same way as Table I.

TABLE II  
NOMENCLATURE IN THE GENUS *POLYTOCA*

	Henrard	Pilger
1. <i>Apluda digitata</i> L. f. Suppl. 434. 1781.	1a	1a
1a. <i>Polytoca digitata</i> (L. f.) Henr. in Meded. Rijks. Herb. Leid: 67:10. 1931.	1a	1a
2. <i>Coix heteroclita</i> Roxb. Fl. Ind. 3:572. 1832.	1a	—
3. <i>Polytoca bracteata</i> R. Br. in Bennett & Brown, Pl. Javan. Rar. 20. tab. 5. 1838.	1a	1a
4. <i>Cyathorbachis Wallichiana</i> Nees ex Steud. Syn. Pl. Gram. 1:403. 1854.	4a	4a
4a. <i>Polytoca Wallichiana</i> (Nees) Benth. in Jour. Linn. Soc. 19:52. 1881.	4a	4a
5. <i>Sclerachne cyathopoda</i> Muell. Fragm. Phytog. Austr. 8:116. 1873.	5a	—
5a. <i>Polytoca cyathopoda</i> (Muell.) F. M. Bailey, Queensl. Fl. 6:1849. 1902.	5a	5a
6. <i>Polytoca macrophylla</i> Benth., l. c. 1881.	6	6
7. <i>Chionachne Massii</i> Balansa in Jour. de Bot. [Paris] 4:78. 1890.	7a	—
7a. <i>Polytoca Massii</i> (Balansa) Schenck ex Henr. l. c. 67:9. 1931.	7a	7a
8. <i>Polytoca javanica</i> Henr. in Blumea 3:241. 1939.	8	8

NOMENCLATURE IN THE GENUS *CHIONACHNE*

	Henrard	Pilger
1. <i>Coix arundinacea</i> Koenig ex Willd. Sp. Pl. 4:203. 1805.	3a	—
2. <i>Coix barbata</i> Roxb. Fl. Ind. 3:569. 1832.	3a	3a
3. <i>Coix Koenigii</i> Spreng. Syst. 1:239. 1825.	3a	3a
3a. <i>Chionachne Koenigii</i> (Spreng.) Thwaites, Enum. Pl. Zeyl. 357. 1864.	3a	3a
4. <i>Coix cryptoides</i> C. Muell. in Bot. Zeit. 19:334. 1861.	3a	—
5. <i>Polytoca semiteres</i> Benth. ex Hook. Fl. Brit. Ind. 7:101. 1896.	5a	—
5a. <i>Chionachne semiteres</i> (Benth. ex Hook.) Henr. in Meded. Rijks. Herb. Leid. 67:16. 1931.	5a	5a
6. <i>Chionachne baurata</i> Hack. in Philipp. Jour. Sci. Suppl. 1:263. 1906.	6	6
7. <i>Chionachne Hubbardiana</i> Henr. in Blumea 3:162. 1938.	7	7

The species of both *Polytoca* and *Chionachne* range in distribution from India to Australia. *Polytoca Massii* is found in Tonkin; *P. Wallichiana* in northeastern India and Pegu; *P. digitata* ranges from India to southern China and Java; *P. cyathopoda* is confined to northern Australia and Queensland; *P. macrophylla* grows in the Malay Archipelago, New Guinea, and the Louisiade Archipelago; *P. javanica* has been reported only from Java by Henrard.

*Chionachne Koenigii* is distributed throughout India and in Tonkin, Ceylon, the Celibes, and Queensland; *Ch. baurata* is endemic to the Philippines; *Ch. semiteres* is found in the Deccan and Burma; *Ch. Hubbardiana* is endemic to Queensland.

The only economic use reported for these grasses is as fodder. *Chionachne Koenigii*, which is widely spread over India, is used as a fodder when young (Duthie, 1888).

#### MATERIALS

All the plants used in this study were grown from seed at the Missouri Botanical Garden, both outdoors and in the experimental greenhouse. Through the Plant Introduction Station, Beltsville, Maryland, seeds of various varieties of *Coix* were obtained from India, Ceylon, the Philippines, Central America, and the Belgian Congo, and large numbers of plants were raised. Since *Coix* forms a polyploid series with haploid chromosome numbers of 5, 10 and 20, it was decided to choose one representative of each of these numbers for cytological study, as follows:

(1) A species with a haploid chromosome number of 5, bearing small, hard, chalk-white false fruits, kindly procured for our purpose from Cuttack, India, by Dr. N. Krishnaswami, Cytogeneticist, Agricultural College, Coimbatore, India.

(2) "Blue Adlay", a variety of *Coix Lacryma Jobi* L., with a haploid chromosome number of 10, obtained from Trinidad through the courtesy of Dr. William L. Brown, Geneticist, Pioneer Hi-Bred Corn Company, Iowa.

(3) A species with a haploid chromosome number of 20, bearing greenish-brown false fruits, collected on the Western Ghats (the mountain range that extends for 800 miles along the southwest and west coast of India), also sent by Dr. N. Krishnaswami.

Specific or varietal names have not been appended to (1) and (3), because their morphological characters do not conform *exactly* to any of the descriptions of *Coix* species met with in the literature.

One species of *Chionachne*—*Ch. Koenigii* (Sprengel) Thwaites ( $n = 10$ ), sent by Dr. N. Krishnaswami from the Millet Breeding Station, Coimbatore, India, is included in this study as is also one species of *Polytoca*—*P. macrophylla* Benth. ( $n = 20$ )—obtained from Trinidad by Dr. William L. Brown.

Full descriptions of the five taxa are given below, and inclusive herbarium specimens are being prepared for distribution.

No members of the genera *Sclerachne* and *Trilobachne* were available for cytological or morphological study.

The following is a key to distinguish the three genera:

- I. Female spikelets enclosed in stony covering formed by modified indurated leaf sheath.....*Coix*
- II. Female spikelets enclosed in hardened covering chiefly formed by indurated glume I.
  - a. Terminal spikes male, lateral spikes mixed or female.....*Polytoca*
  - b. All spikes with flowers of both sexes.....*Chionachne*

(1) *Coix* from Cuttack, India.—

*Root-system* very much branched with extremely fine roots. *Culm* erect with numerous basal leaves. *Leaf-blades* linear, very narrow, up to 5 mm. broad, the longest leaves attaining a length of about 60 cm.; prominent white midrib; at union with sheath a well-marked suture which is narrow in the middle and fans out on either side; upper leaf surface sparsely set with hairs each arising from a colorless, crateriform gland. *Sheaths* ribbed, dotted on the outer face with glandular hairs similar to those of the blade. *Inflorescences* axillary, on triangular peduncles, as many as 8 arising from one node; *false fruit* small compared to most other varieties of *Coix*, 8 mm. long and 5 mm. in diameter, flattened on one side, often constricted towards the top, turbinate, chalk-white, hard. *Male portion* of the inflorescence up to 3.5 cm. long. *Glume I* 1 cm. long, lanceolate-ovate, slightly falcate, emarginate, the margins reflexed, the glume thereby 2-keeled, enclosing glume II, the keels winged, one of them throughout, the other only in its upper half, the wings serrate. *Glume II* about the length of glume I, acute, entire, margins infolded.

This description comes fairly close to that given by Mimeur (1951) for her species, *Coix poilanei*, endemic to Laos. The finely branched root-system, the numerous basal, narrow, linear leaves, and especially the dimensions and color of the false fruits, coincide with her description of *C. poilanei*. She says, however, that "les feuilles sont en continuité directe avec les gaines dont elles ne se distinguent pas", whereas in our plant the blades are separated from the sheaths by a distinct suture. The glands on the sheath are colorless and not brown as stated by Mimeur. Also, for the male spikelets she reports "une seule fleur par épillet," while the spikelets of our plant exhibit the 2-flowered condition. In referring to her species, she remarks that it is "très proche de *Coix aquatica*" (*C. gigantea* var. *aquatica* Watt). The chromosome number of the plant under discussion is  $n = 5$ , which is the same as that determined for var. *aquatica* by Mangelsdorf and Reeves (1939).

(2) "Blue Adlay", *Coix Lacryma Jobi* L., from Trinidad.—

This is the wild "*Coix Lacryma-Jobi* proper" of Watt to which he gave the varietal name *typica* and of which he speaks as "the normal form" referring to the false fruits.

*Stem* erect. *Leaf-blades* lanceolate, broad, up to 3.5 cm. in width, in length variable, up to 56 cm., auriculate, glabrous, "except for the double row of ascending teeth along each of the veinlets of the upper surface—a peculiarity that gives the texture of the leaf the appearance of being embroidered and makes it backwardly hispid" (Watt, 1904). Writing further about this character, Watt says: "all the

forms of this species are at once recognized by the texture of the leaf and its peculiar scabrosities." *Ligule* membranous; union of blade with sheath marked by a broad suture. *Sheaths* quite smooth. *False fruits* ovoid-oblong, 10–11 mm. long, 7 mm. in diameter, hard, smooth, polished, bluish-white. *Male portion* of the inflorescence up to 3.5 cm. long, spikelets in two's or three's. *Glume I* 7 mm. long, lanceolate-ovate, emarginate, strongly keeled, winged in the upper half, wings serrate. *Glume II* about the length of glume I, acute, margins infolded, entire.



Text-fig. 1. *Coix poilanei* Mimeur; fig. 2. "Blue Adlay"; fig. 3. *Coix gigantea* Koen: ex Roxb. All about  $\frac{1}{2}$  natural size.

(3) *Coix* from the Western Ghats, India.—

*Stem* perennial, erect. *Leaf-blades* linear-lanceolate, between 2 and 2.5 cm. broad and up to 30 cm. long; both upper and lower surfaces sprinkled with hairs each arising from a crateriform gland; margins serrate. *Sheath* also with crateri-

form glands bearing hairs, but here the glands of a dark reddish hue; union of blade with sheath marked by a broad suture. *Ligule* membranous; just above ligule, at base of leaf, a tuft of stiff hairs similar to those on the rest of the leaf. *Inflorescences* axillary, 2 or more spikes emerging from the sheath of a short leaf, the spike emerging first, being borne on a longer peduncle than that of the others; peduncles flattened on one side, glabrous; *false fruits* elongate, pyriform, 1 cm. long, 5–6 mm. in diameter, mouth oblique, pale green with brown markings, slightly flattened on one side. *Male spikes* up to 4 cm. long, drooping, spikelets mostly in 3's, the lateral ones sessile and the middle one pedicellate, each 2-flowered. *Glume I* 9 mm. long, ovate-oblong, emarginate, the margins reflexed, the glume thereby 2-keeled, enclosing glume II, the keels winged throughout, margins of the wings serrulate. *Glume II* winged, acute, margins entire.

The description above corresponds in general to that given for *C. gigantea* by Roxburgh (1832) and that by Watt (1904). The important differences are discussed below:

1. Roxburgh describes the sheaths as "smooth", and Watt as "quite glabrous and eglandular". In the specimens under discussion, however, the sheaths are sprinkled with sharp hairs arising from crateriform glands of a dark reddish color.

2. The leaves are not "narrow" and "linear" as in Watt's description but "about 1 inch broad" as in Roxburgh's. They are evidently subject to variation, for Watt speaks of "... Sir J. E. Smith's sheet of *C. gigantea* ... which has gland-dotted broad leaves ..."

3. With regard to the false fruits, Watt describes them as "flattened on one side, and with 2 furrows longitudinally on the flat face ...". While the ones described here are flattened on one side, no furrows are present, nor are any furrows mentioned by Roxburgh or by Mimeur (1951).

The name *Coix gigantea* is retained for the entity used in this study. The uncertainty of its correct application is indicated by a question mark. The chromosome number of " $2n = 40$ " tallies with that reported for *C. gigantea* by E. K. Janaki Ammal (Darlington & Janaki Ammal, 1945).

(4) *Polytoca macrophylla* Benth.—

*Stem* robust, erect. *Leaf-blades* up to 55 cm. long, between 2.5 and 3.5 cm. broad, glabrous, lanceolate, acuminate, cordate at base; margins dentate; midrib prominent; union with sheath marked by a broad suture. *Sheath* glabrous. *Ligule* narrow, membranous. *Female spikelets* 1 cm. long, variable in glume I which may be entire or toothed at summit or have 2 lateral teeth, sometimes 1. *Male spikelets* in pairs, each pair made up of 1 pedicellate and 1 sessile spikelet. *Glume I* up to 11 mm. long, acute, asymmetrical in the pedicellate spikelet, margins infolded with a broad wing along the fold on one side, wing serrate, other side merely folded slightly, lanceolate-ovate in the sessile spikelet, margins infolded, winged along the fold symmetrically on both sides. *Glume II* laterally compressed, folded along the



Text-fig. 4. *Polytoxa macrophylla* Benth. About  $\frac{1}{3}$  natural size.

middle, keeled along the fold in the pedicellate spikelet; keel winged in upper half, wings serrate, very slightly keeled in the sessile spikelet. The chromosome number agrees with Avdulov's determination (1931) of  $2n = 40$ .

(5) *Chionachne Koenigii* (Sprengel) Thwaites.—

*Stem* perennial, erect, freely branching at the base. *Leaf-blades* about 40 cm. long (said to attain a length of 2 feet, Ranga Achariyar, 1921), up to 1.2 cm. broad, linear, with a prominent midrib; union with sheath well-marked by a suture. *Sheaths* with scattered tubercle-based hairs at the base, sheath margins hairy. *Ligule* membranous; nodes densely ringed with hairs. *Inflorescences* axillary, most of them clustered at the ends of very long peduncles which are flattened or slightly concave on one side; leaf, in the axil of which several peduncles arise, with a sheath about 2.5 cm. long, the blade, although shorter than normal, fairly well-developed; each spike in a cluster enclosed in its lower portion by a bladeless awned sheath, 1–1.5 cm. long; 1, sometimes 2, of the lowermost spikelets female, borne in pairs of which one spikelet is sessile and the other pedicellate, the pedicel partly fused with the rhachis; rhachis pubescent. *Female spikelets* oblong, 5.5 mm. long, en-



Fig. 5. *Chionachne Koenigii* (Spreng.) Thwaites. About  $\frac{1}{2}$  natural size.

closed in glume I which becomes shiny and hard at maturity; at the union of the edges of the glume a groove through which the rhachis passes. *Male spikelets* 2-flowered. *Glume I* up to 8 mm. long, acute, pubescent, the margins infolded, the glume winged along the fold on both sides in the sessile, but only on one side in the pedicellate, spikelet; wings serrate. *Glume II* acute, laterally compressed and folded along the middle with a pronounced keel along the upper half of the fold in the pedicellate spikelet, only slightly keeled in the sessile.

## CYTOLOGY

A number of cytologists have definitely established the existence of the chromosome numbers in multiples of 10 in two of the three genera of the New World Maydeae, *Euchlaena* and *Zea*. *Tripsacum* is a well-known exception; all the species and varieties have 18 pairs of chromosomes or multiples of this number. Among the Oriental Maydeae the gametic or reduced number most often encountered is also 10; this is evident from the following table:

	Gametic Number	Somatic Number	
1. <i>Coix Lacryma Jobi</i> L.	—	20	Kuwada, 1915
2. <i>Polytoca macrophylla</i> Benth.	—	40	Avdulov, 1931
3. <i>C. Lacryma stenocarpa</i> Oliver	—	20	Reeves and Mangelsdorf, 1935
4. <i>Sclerachne punctata</i> Brown	—	20	Reeves and Mangelsdorf, 1935
5. <i>C. Lacryma-Jobi</i> var. "Ma-yuen" (Roman.) Stapf	—	20	Mangelsdorf and Reeves, 1939
6. <i>Polytoca barbara</i> Stapf [ <i>Chionachne Koenigii</i> (Spreng.) Thwaites]	—	20	Mangelsdorf and Reeves, 1939
7. <i>C. aquatica</i> Roxb.	5	10	Mangelsdorf and Reeves, 1939
8. <i>C. gigantea</i> Koen. ex Roxb.	—	20, 40	E. K. Janaki Ammal, 1945
9. <i>C. poilanei</i> Mimeur (?)	5	10	Nirodi, 1955

The numbers in all the above taxa except 3, 4, and 7 have been confirmed in this study. *C. aquatica* (Roxb.) and *C. poilanei* Mimeur (?) are exceptional in having the gametic number 5, which is the lowest found in the Gramineae and reported so far only for the unrelated genera *Briza* and *Anthoxanthum* and for five species from two of the sub-genera of the *Sorghastreae*.

## METHODS

For cytological study entire male spikes were fixed in a solution of glacial acetic acid and absolute alcohol 1:3. Two days to a week later they were transferred to 70 per cent alcohol and stored under refrigeration. Young spikes that had barely begun to emerge from the ensheathing spathe were found to be at the right stage for meiotic studies. Temporary smears were stained either with aceto-carmine or with aceto-orcein. A few were made permanent by using the dry-ice freezing technique described by Conger and Fairchild (1953).

While pachytene smears of *Coix* were being examined to investigate the possibilities for making chromomere analyses, stray cells from somatic anther-tissue were noticed showing well-stained and well-spread diploid chromosomes. These were assumed to be tapetal cells. Proof of the assumption was obtained when young anthers fixed in a solution of 3 parts absolute alcohol to 1 of glacial acetic acid were embedded in paraffin, sectioned and stained with crystal violet.

Smears made for the observation of tapetal chromosomes were treated in a slightly different way from smears made for meiotic studies. The contents of an anther were squeezed out in a drop of stain and well stirred with an iron needle. The debris was allowed to remain. After the placing of the cover-slip the slide was heated over a spirit-lamp and pressed vigorously between blotters to release the tapetal chromosomes from the nuclear membrane and spread them evenly.

#### CHROMOSOME MORPHOLOGY

The tapetal cells of *Coix*, *Polytoca* and *Chionachne* go through the process of endomitosis. At the time the pollen mother cells are undergoing pachytene the tapetal cells have already passed from the uninucleate to the binucleate condition, and smears made at this stage show many of them in endoprophase. Speaking of endoprophase stages in tomato tapetum, Brown (1949) remarks that they are "valuable for a study of somatic chromosome morphology". The same can be said of the three genera of grasses dealt with in this paper. Observations on chromosome morphology were based almost entirely on tapetal cells from anther smears. At about the middle of endoprophase, the chromosomes reach a particularly favorable degree of contraction and stain deeply enough to be identified individually. Sectioned material shows them surrounded by a nuclear membrane but in smearing the membrane may be lost.

*Coix poilanei* Mimeur (?).—This species, together with *Coix gigantea* var. *aquatica* Watt, occupies the lowest position in the polyploid series formed by *Coix*. Its somatic chromosome number determined both from root-tips and tapetal cells was found to be 10. At very early endoprophase the chromosomes are very much attenuated and are up to five times as long as they are at the end of this phase. They are very loosely coiled, and though they often overlap they can easily be traced throughout their length (pl. 8, fig. 1).

A characteristic of tapetal chromosomes in *Coix* is their striking differentiation into regions of different staining capacity. Extremely lightly staining areas occur which are very constant in their location at a particular stage. These stand out in good contrast to the deeply staining portions, thus making the chromosomes easy to identify. Usually, and especially when they occur at the ends of the chromosomes, these achromatic regions are visibly split, with the daughter chromatids often divergent. A point to be noted at this stage is that quite often along the achromatic regions the chromomeres are visible, and two of these may be seen side by side in each diverging half of a chromosome indicating that it is made up of four chromatids (pl. 8, fig. 3A). "Achromatic" as used here is a relative term. These regions appear pale in comparison with the remaining portions of the chromosome. The chromomeres in the achromatic regions often stain clearly enough to be distinctly visible.

The five chromosomes of the haploid set have been designated A, B, C, S and D, S standing for the satellite chromosome (pl. 8, figs. 2-6). Chromosome A has a

very long achromatic region at one end, and Chromosome B has shorter achromatic regions at both ends. Chromosome C has two achromatic regions, one in each arm midway between the end and the centromere. Chromosome S is recognized by the presence of the satellite. In its elongated state it also exhibits an achromatic region in either arm but this may disappear on contraction. Chromosome D is very like Chromosome S but devoid of the satellite and shorter.

Figures 2-6 of pl. 8 show tapetal chromosomes in varying stages of contraction. Even when quite strongly contracted they can be told apart—Chromosome A and B by the difference in number and location of the achromatic regions, Chromosome S by the satellite, Chromosomes C and D by their difference in length, Chromosome D being shorter. When the achromatic regions do not occur at the ends of the chromosomes their contraction leaves wide gaps in the body of the chromosomes. Figure 6 of pl. 8 shows a late endometaphase with most of the chromosomes divided throughout but held together at the centromeres. The diverging arms give them a characteristic cruciform appearance.

Owing to the fact that there may be two or even three places along the chromosomes that show clear spaces and look like centromeres, the true position of the spindle-attachment region was ascertained from this stage and from root-tip squashes. Root-tip chromosomes examined at anaphase were found to be bent into V's with equal or slightly unequal arms indicating that all the chromosomes had median or sub-median centromeres. Plate 10, fig. 2, shows one large tapetal nucleus containing the tetraploid number of chromosomes after the completion of one endomitosis. Since the chromosomes are in early endoprophase it is probably entering a second cycle. It was not ascertained whether a second endomitosis is completed nor what degree of ploidy a tapetal cell is capable of attaining.

When the chromosome number for *Coix aquatica* Roxb. was reported by Mangelsdorf and Reeves (1939) to be  $2n = 10$  they observed that "no variation in the number was found". In *C. poilanei* Mimeur (?), though the tapetal cells most often showed 10 chromosomes, occasionally cells were found where 12 and rarely 11 were present. Though the nuclear membrane is ruptured on smearing, it is possible to recognize the contents as belonging to a single nucleus. Thus the possibility that the extra chromosomes might have been displaced from a neighboring nucleus due to the pressure exerted while smearing is eliminated. Besides, when pollen mother cells were examined, occasionally 6 bivalents were found at diakinesis; fig. 1 of pl. 11 shows an MI telophase where 6 chromosomes have been distributed to either pole. Due to the way in which the anthers were collected it was not possible to say with certainty whether this variation in number was between plants or between spikelets of one plant.

*Coix Lacryma Jobi* L.—The tapetal cells of three kinds of this species were smeared to see if varietal differences were manifest in the chromosomes. The first was "Blue Adlay", i. e. var. *typica* from Trinidad (described above). The other two were two kinds of var. "Ma-yuen". Cultivated forms of *C. Lacryma jobi* have been placed under this varietal name. Cultivation makes itself evident by

turning the stony capsule spathe soft and brittle and striated. One of the two kinds mentioned came from the Philippines and has chalk-white, brittle, and very faintly striated capsular spathes. The shape is that of var. *typica*. The other has dark brown, brittle and strongly striated capsular spathes, somewhat elongated and with a mouth larger than usual. For convenience these shall be referred to as var. "Ma-yuen (1)" and var. "Ma-yuen (2)".

A general similarity is obvious in the chromosome sets of these three kinds of *Coix*. On the whole, the chromosomes are smaller than in the 10-chromosome species. Another difference is that achromatic regions, when they occur, are usually found only towards the ends of the chromosomes. Therefore, the pronounced gaps that are left in the body of the chromosomes after a certain degree of contraction described in the 10-chromosome species are rarely met with here.

The attempt to discern homologues among the somatic chromosome sets of var. *typica*, var. "Ma-yuen (1)" and var. "Ma-yuen (2)" was confined to those chromosomes provided with pronounced achromatic ends as they helped as markers. They have been marked by small letters of the alphabet (pl. 8, figs. 7 and 8; pl. 9, fig. 1). The nucleolus chromosomes are very similar in all three, with distal ends achromatic and split. In var. *typica* and var. "Ma-yuen (2)" both nucleolus chromosomes in a diploid set possess satellites but in var. "Ma-yuen (1)" a satellite was seen on only one of them. Its homologue is seen to be in connection with the nucleolus but no satellite was observed. As in the 10-chromosome *Coix*, the centromeres are all median or sub-median which agrees with Taylor's observations (1925) on root-tip chromosomes. This is fairly clear in the tapetal chromosomes (pl. 8, figs. 7 and 8; pl. 9, fig. 1) but much more evident in pl. 11, fig. 7, where meiotic chromosomes of var. *typica* are seen in second metaphase. The chromatids prior to separation are held together at the centromere which stands out markedly.

*Coix gigantea* Koen. ex Roxb. (?).—Here the chromosomes, in spite of being twice as numerous as in the varieties of *C. Lacryma Jobi*, are no smaller. In fact, two pairs approach A and B in size, the two largest chromosome pairs in the 10-chromosome *Coix*. *Coix poilanei*? (pl. 8, fig. 3), the varieties of *C. Lacryma Jobi* (pl. 8, figs. 7 and 8), and *C. gigantea* (?) (pl. 8, fig. 2) all show their respective tapetal chromosomes in endoprophase at more or less the same degree of contraction. By comparing these figures it can be seen that many of the chromosomes of *C. gigantea* (?) are intermediate in size between those of *C. poilanei* (?) and of the 20-chromosome *Coixes*.

The centromeres of *C. gigantea* chromosomes stand out more clearly than those of any of the other kinds described so far. Again, all of them are either median or sub-median. This is confirmed by fig. 1 of pl. 13, where the chromosomes are in prophase of the second meiotic division. The chromatids are held together only at the centromeres and the four diverging arms of each chromosome are seen to be approximately equal.

Due to the much larger number of chromosomes present in *C. gigantea*? it was difficult to obtain cells which showed them spread at an appreciable distance from

one another. The cell shown in fig. 2 of pl. 9 was stained in aceto-orcein and does not show the nucleolus. Diakinesis stages clearly indicate the presence of two pairs of nucleolus chromosomes. From observations of carmine-stained tapetal cells it was seen that two of the nucleolus chromosomes were similar to the ones indicated by arrows (pl. 9, fig. 2). Although only one pair of chromosomes has been indicated (by X's) in var. "Ma-yuen (2)" and in *C. gigantea*? as being probably homologous, a general similarity between the genomes of the 20- and the 40-chromosome Coixes is very much in evidence. The characteristic achromatic regions are found in practically all the chromosomes of *C. gigantea*? and, as in the varieties of *C. Lacryma Jobi*, are mostly confined to the ends. The achromatic ends are visibly split and often divergent.

Occasionally, tapetal cells were noticed which had two extra chromosomes. It was not ascertained how often this occurred in the tapetal cells but when studying the meiosis, counts were made in a hundred pollen mother cells at diakinesis. Of these only two were found with an extra bivalent and one with one bivalent missing. The variation seems to be within plants.

*Polytoca macrophylla* Benth.—The tapetal chromosomes of this species differ from those of *Coix* in that there is no conspicuous differentiation into chromatic and achromatic regions. They stain more or less uniformly, as can be seen in pl. 10, fig. 3, where they are in endoprophase. Two nucleolus chromosomes with satellites can be observed in the same figure. Figure 4 of this plate shows them at endometaphase, more condensed and already divided as shown by the longitudinal split apparent along each chromosome. Conspicuous constrictions indicate the position of the centromeres. Plate 10, fig. 5, shows a late endometaphase. The divided halves of each chromosome are seen to diverge and are held together only at the centromere. This is a stage corresponding to the one in *C. poilanei*? (pl. 8, fig. 6). Such cruciform configurations due to union only at the centromeres are sometimes characteristic of colchicine-treated plants undergoing c-mitoses. Levan (1938) describes it in *Allium*. Brown (1949), speaking of endomitotic cycles in the tapetum of tomato, says that in some respects they resemble mitoses upset by treatment with colchicine. No cruciform stage, however, nor any evidence of protracted union at the centromere was observed by him. It is not known whether the union at the centromere in *Polytoca macrophylla* and *Coix poilanei*? is much protracted but the cruciform configurations form a definite stage in the endomitotic cycle of the tapetum in these two instances.

In the contracted condition at endometaphase (pl. 10, fig. 4), *Polytoca* chromosomes bear a likeness to somatic chromosomes of corn treated with paradichlorobenzene. This produces effects very similar to those of colchicine, one of which is to shorten the chromosomes much beyond their normal length.

*Chionachne Koenigii* (Sprengel) Thwaites.—In this species of *Chionachne* the tapetal chromosomes, like those of *Polytoca macrophylla*, stain more or less uni-

formly. Plate 9, fig. 3, shows them in endoprophase. The presence of satellites on the nucleolus chromosomes is doubtful. What seemed like satellites were only observed in one cell in which the chromosomes were in early endoprophase and were thin and long. They were not observed either in root-tip chromosomes or in pollen mother cells at diakinesis. The centromeres, though not marked by conspicuous constrictions as in *Polytoca*, are easy to locate. At endometaphase, the chromosomes are very much contracted and the beginnings of a longitudinal split can be observed in some of them.

#### MEIOSIS

Observations were made on pachytene smears of *Coix*, *Polytoca* and *Chionachne*. The pachytene stage in *Coix* was found to be markedly different from that of *Polytoca* and *Chionachne* in that conspicuous knobs were observed in *Coix* that were absent in the other two genera. The part played by chromosome knobs in the determination of relationships between maize and its relatives is only too well known. Considering this feature of chromosome morphology, it could be assumed that of the three genera *Coix* is the most closely related to the New World Maydeae. Longley (1941) pointed out the similarity between the chromosomes of *Zea* and those of *Coix*. Comparing the bivalents of corn and *Coix*, he showed that the variation in size in the two sets of bivalents was very similar.

A general similarity seems even more apparent on comparing the pachytene stages of a 20-chromosome *Coix* with those of corn. A glance at fig. 7 of pl. 10, however, shows that of the six knobs observable only one is internal and the rest terminal, a condition at variance with that in corn where the majority of knobs are internal. In this respect, therefore, *Coix* seems to resemble *Euchlaena* or *Tripsacum* more than corn (knobs in *Euchlaena* are both internal and terminal and in *Tripsacum* the majority are terminal). Figure 7 shows a pachytene smear from a variety of *C. Lacryma Jobi* obtained from the Sugar Cane Breeding Station, Coimbatore, India. From a study of its gross morphology this plant is classified as var. *typica*. Yet the number of its knobs differs widely from that of var. *typica* from Trinidad ("Blue Adlay"). This variation is quite in accordance with the situation in corn. Longley (1939), writing about such variation in knob number in corn, observes that it is "frequently very pronounced when plants of varieties from different geographical regions are compared". In corn, knob-forming centres can exist but not be evident unless a knob is formed at the knob-forming point, an occurrence which depends on several factors, one of them being the amount of knob material available (Longley, 1939). Figure 6 of pl. 10 shows a single chromosome of "Blue Adlay", with an elongated, terminal knob. In appearance and position it is exactly like one of the terminal knobs of var. *typica* from Coimbatore. It may well be that the position and number of knob-forming centres are similar in the two plants but that knobs make their appearance at more centres in var. *typica* from Coimbatore than in var. *typica* from Trinidad. The knobs of

var. *typica* from Coimbatore vary in appearance from large, somewhat elongated ones to smaller, more rounded ones (pl. 10, fig. 7).

The pachytene chromosomes of *C. poilanei*? were in too tangled a state to allow proper observation. The knobs in *C. gigantea*? (pl. 12, fig. 1) are small, rounded and mostly terminal. No knobs were observed in *Polytoca macrophylla* and *Chionachne Koenigii*.

If a chromomere analysis of *Coix* chromosomes were undertaken it would seem best to start with varieties of *C. Lacryma Jobi*. The pachytene stages are easy to handle and the chromosomes spread out well enough to be examined. The chromosome number being the same as in corn, similarities with and differences from corn chromosomes would be easier to identify. Only late diplotene stages of *C. poilanei*?, "Blue Adlay" and *Polytoca macrophylla* were observed. These showed a maximum of three chiasmata per bivalent in the two *Coix*es and up to five in *Polytoca* (pl. 9, fig. 4; pl. 13, fig. 3). In *C. poilanei*? the chromosome pairs could be identified at this stage and have been marked in the figure with the same letters used to identify tapetal chromosomes. By late diakinesis in *C. poilanei* (?) (pl. 9, fig. 5), all except the satellite bivalent are completely terminalized and lie side by side or are connected at the ends by slender filaments. The bivalent of satellite chromosomes is still connected at the satellite end and free at the other, forming a V. All five bivalents could easily be identified even in this contracted phase and have been indicated by letters as in previous figures of *C. poilanei* (?).

In "Blue Adlay", five rings and five V's were observed to make up the ten bivalents (pl. 11, fig. 2); the achromatic ends mentioned in describing the tapetal chromosomes are still noticeable and are especially clear in the distal end of the satellite bivalent.

Diakinesis in *C. gigantea* (?) deviates somewhat from the perfectly normal formation of bivalents exhibited by *C. poilanei* (?) and "Blue Adlay". One association of 4 chromosomes was seen in some pollen mother cells and some showed two rings of 4 (pl. 12, fig. 5) but the majority had 20 bivalents. These three kinds of behavior were found in pollen mother cells from the same spikelet. Evidently, the two sets of 4 chromosomes that tend to form rings possess some incipient homology.

*C. gigantea* (?) presumably has two pairs of nucleolus chromosomes. Two bivalents were often seen in association with the nucleolus at diakinesis and one pollen mother cell was observed which had two distinct nucleoli each associated with a bivalent. But the prominent satellites characteristic of *Coix* were only seen to be displayed by one of the bivalents (pl. 12, fig. 6).

Both *Polytoca macrophylla* and *Chionachne Koenigii* behave normally at diakinesis, regularly forming 20 and 10 bivalents respectively (pl. 13, fig. 4; pl. 14, fig. 3). The former has satellites to its two nucleolus chromosomes but none were observed in *Chionachne*.

Formation of metaphase plates and separation at anaphase I take place in the normal fashion. There is an orderly migration to the poles; and no formation of

bridges, lagging chromosomes, nor any other irregularities were observed in any of the five plants (pl. 9, fig. 6; pl. 11, fig. 3; pl. 12, fig. 7; and pl. 14, fig. 4).

At telophase I the chromosomes are seen to have formed two compact groups. By the time they emerge from telophase I and enter prophase II, the arms of the component chromatids of each chromosome are seen to diverge from the centromere with the result that the chromosomes appear cruciform. A nucleolus has been re-formed in each group. This behavior is similar in all five taxa under discussion (pl. 12, fig. 3; pl. 11, fig. 6; pl. 13, fig. 1; pl. 14, fig. 1).

At this stage, the second meiotic prophase, a curious body was seen to occur regularly in each of the two groups of chromosomes in *C. gigantea* (?). It appeared to be composed of a few darkly staining granules embedded in a lightly staining matrix (pl. 14, fig. 1). It varied in shape, being sometimes small and rounded, sometimes larger and lens-shaped. The number of granules also varied. An attempt to investigate the nature of this body was made by halving an anther containing pollen mother cells in second prophase and staining one half with aceto-carmin and the other with aceto-orcin. With aceto-carmin both nucleolus and the body showed up clearly, while the orcin-stained preparation stained neither the nucleolus nor the matrix. The granules showed extremely faintly. It would seem from this evidence that the body was in some way connected with the nucleolus. It was not seen in contact with any of the chromosomes or with the nucleolus, and so far as was observed was not seen to be in later stages.

The remaining stages of the second meiotic division leading to tetrad formation are completed in normal fashion. In *C. gigantea*? and *Ch. Koenigii* at anaphase II separation of chromatids and migration along the spindle may not take place simultaneously in both cells (pl. 13, fig. 2; pl. 14, fig. 6).

#### *Relationship between Chromosome Number and Gross Morphology.*—

*Coix Poilanei*?, with 10 somatic chromosomes, is essentially a small plant and even when grown outdoors did not exceed a height of three feet. The varieties of *C. Lacryma-Jobi*,  $2n = 20$ , of which several forms of var. "Ma-yuen" and var. *typica* from different regions were raised, showed a wide variation in size, some attaining a height of 3 feet, others growing 9 feet tall. Most of them averaged 7–8 feet.

*Coix gigantea*?, with the highest chromosome number ( $2n = 40$ ), exhibits characteristics typical of polyploids. Roxburgh (1832) describes it as attaining a height of 8–15 feet. Our plants of *C. gigantea*? were only between 5 and 6 feet high, but the leaves were coarser than in the two other species and the plants came into flower much later.

#### *Relationship between Chromosome Number and Geographical Distribution.*—

Species of *Coix* seem to have reached an optimum in the somatic number of 20. While the 10- and 40-chromosome kinds are more or less restricted in their distribution, *C. Lacryma Jobi* and its varieties have spread over the world.

## DISCUSSION

On finding that accurate chromosome counts could be made from tapetal cells, a study of their chromosome morphology was undertaken. While tapetal chromosomes at the right stage for study were being sought it gradually became apparent that they undergo what is essentially a process of endomitosis. Endomitosis in tapetal cells was first reported by Witkus (1945) in *Spinacia*. Brown (1949) showed that tapetum endomitosis in tomato differed in some respects from the process in *Spinacia*. In both cases the process ends in the formation of polyploid nuclei but whereas in *Spinacia* the nuclear membrane remains intact throughout and the chromosomes are irregularly distributed, in tomato there is a breakdown of the nuclear membrane and the chromosomes form clumps or are arranged in plates at endometaphase.

In spite of the breakdown of the nuclear membrane, Brown retains the term "endomitosis," explaining that "lack of movement of the chromosomes on a spindle rather than persistence of a nuclear membrane would seem to be the better criterion of endomitosis."

In the present study the behavior of tapetal cells follows a somewhat similar pattern to that described in tomato. The cells are uninucleate to start with but soon become binucleate following a normal mitosis, i. e., with spindle formation but without the formation of a cell wall. The chromosomes become visible as separate entities at endoprophase and contraction commences. At endometaphase the chromosomes are very much contracted and the beginning of a longitudinal split, prior to anaphase separation, is distinctly noticeable (pl. 8, fig. 9; pl. 10, fig. 4). However, the cruciform configurations at late metaphase described in *C. poilanei*? and *Polytoca* and presumably present in the other three taxa are reported by Brown to be absent in tomato.

At endoanaphase the chromosomes form dense clumps. The fact that the chromosomes fall apart at this stage was only gathered from the small size of stray chromosomes at the periphery of the clumps.

That the completion of endomitosis results in tetraploid nuclei was concluded from the larger size of many resting nuclei and from instances like the one portrayed in pl. 10, fig. 2, where a tetraploid nucleus of *C. poilanei*? is shown with its chromosomes in endoprophase of a second endomitosis. Whether this is concluded with the formation of an octoploid nucleus is not known. Except in *C. poilanei*? no tetraploid nuclei were observed in a state in which the chromosomes could be counted. For this to be possible the chromosomes would have to emerge from the resting stage and start on a second endoprophase, and this does not seem to happen in the other four taxa, and was only rarely observed in *C. poilanei*? Presumably then, endomitotic activity stops after one division and the formation of tetraploid nuclei, i. e., two tetraploid nuclei per tapetal cell. Brown reports three endomitotic cycles as normal to tapetal cells in tomato.

Sectioned material at endoprophase showed the nuclear membrane intact and fig. 9 of pl. 8 shows an endometaphase in var. "Ma-yuen (1)" with the membrane

still intact. Whether it disappears at a later stage is not definitely known but it seems unlikely. Assuming that it does not, the endomitosis in *Coix*, *Polytoca* and *Chionachne* resembles *Spinacia* regarding this point. According to Brown, in tomato the membrane disappears toward late endoprophase.

From what study has been made on *Coix* chromosomes it would appear that the various species and varieties dealt with in this paper form a fairly homogeneous group, with 5 as the basic chromosome number. *C. poilanei*? would then be considered a diploid species, *C. Lacryma Jobi* and its varieties tetraploids, and *C. gigantea*? an octoploid. Morphologically, the octoploid is similar to the diploid in an outstanding characteristic, the presence of crateriform glands bearing hairs. (Watt considers this characteristic as one of the more important ones that separate what he terms "the *gigantea-aquatica* series" from the *Lacryma-Jobi* series). In its chromosomes, however, the octoploid is more like the tetraploids.

Since no crossing experiments were undertaken for this study any hypothesis regarding the possible origin of the tetraploid and octoploid should be made with the necessary caution. It could be surmised that the tetraploids arose by a crossing of two similar diploids and a doubling of the chromosome number of the hybrid. They function like true diploids forming no multivalents. In the octoploid two nucleoli have been observed, and there are two sets of nucleolus chromosomes. Multivalent configurations are found. It probably originated from the tetraploid as an autopolyploid. Since its origin, its genomes have undergone changes so that it has come to function essentially as a diploid but the occasional formation of tetravalents indicates its autopolyploid beginnings.

On the basis of its pachytene chromosomes, *Coix* as a genus seems closer to the New World Maydeae than to *Polytoca* and *Chionachne*. In staining reactions, as previously described, *Polytoca* and *Chionachne* behave differently from *Coix*. Morphologically, they are similar in having the walls of their fruit-cases formed from the hardened first glume, whereas *Coix* has hardened, modified leaf-sheaths. The probability must not be overlooked that investigation of species of *Polytoca* and *Chionachne* other than those treated here might disclose the presence of pachytene knobs. The resemblance of endometaphase chromosomes of *Polytoca* to those of artificially shortened somatic chromosomes of corn has been mentioned. On the basis of the present evidence, it would seem that *Polytoca* and *Chionachne* bear a closer affinity to each other than to either *Coix* or to the New World Maydeae.

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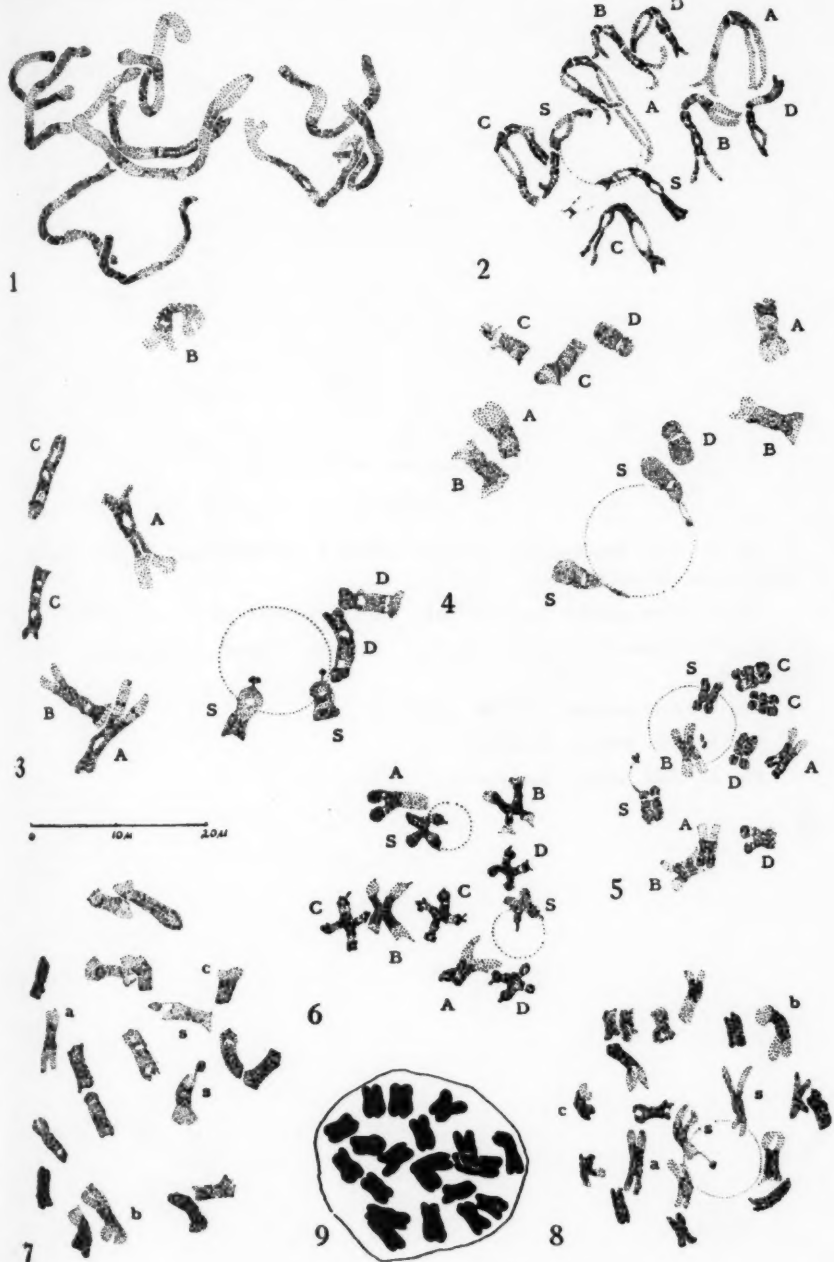
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#### EXPLANATION OF PLATE

##### PLATE 8

- Figs. 1-4. *Coix poilanei* Mimeur. Tapetal chromosomes in endoprophase.  
 Fig. 5. *Coix poilanei*. Tapetal chromosomes in endometaphase.  
 Fig. 6. *Coix poilanei*. Tapetal chromosomes in late endometaphase.  
 Fig. 7. "Blue Adlay" (*C. Lacryma Jobi* var. *typica* Watt), from Trinidad. Tapetal chromosomes in endoprophase.  
 Fig. 8. Var. "Ma-yuen (1)" (*C. Lacryma Jobi* L. var. "Ma-yuen" Stapf). Tapetal chromosomes in endoprophase.  
 Fig. 9. Var. "Mayuen (1)". Tapetal chromosomes in endometaphase.



NIRODI—ASIATIC RELATIVES OF MAIZE

## EXPLANATION OF PLATE

## PLATE 9

Fig. 1. Var. "Ma-yuen (2)" (*C. Lacryma-Jobi* L. var. "Ma-yuen" Stapf). Tapetal chromosomes in endoprophase.

Fig. 2. *Coix gigantea* Koen. ex Roxb. Tapetal chromosomes in endoprophase.

Fig. 3. *Chionachne Koenigii* (Spreng.) Thwaites. Tapetal chromosomes in endoprophase.

Fig. 4. *Coix poilanei*. Mimeur. Diplotene.

Fig. 5. *Coix poilanei*. Diakinesis.

Fig. 6. *Coix poilanei*. Anaphase I.

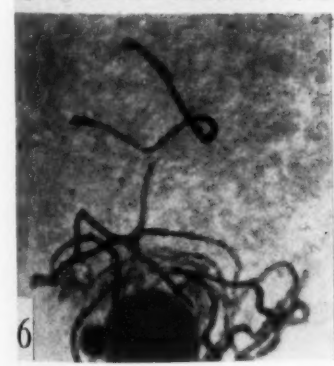
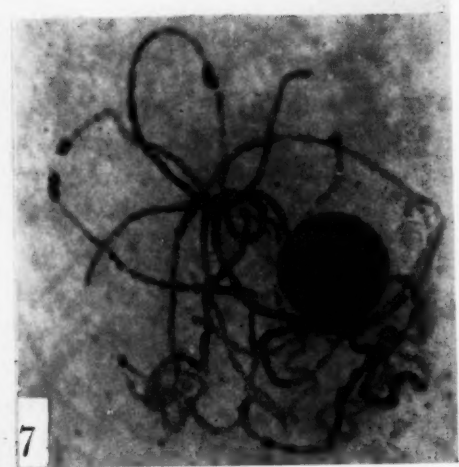
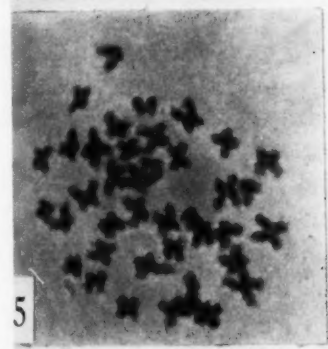
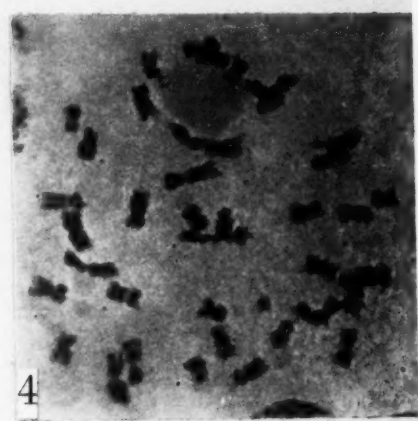
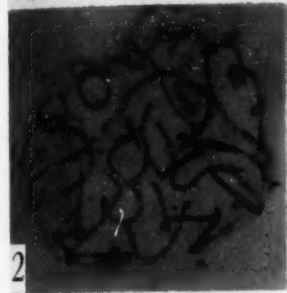


NIROTI-ASIATIC RELATIVES OF MAIZE

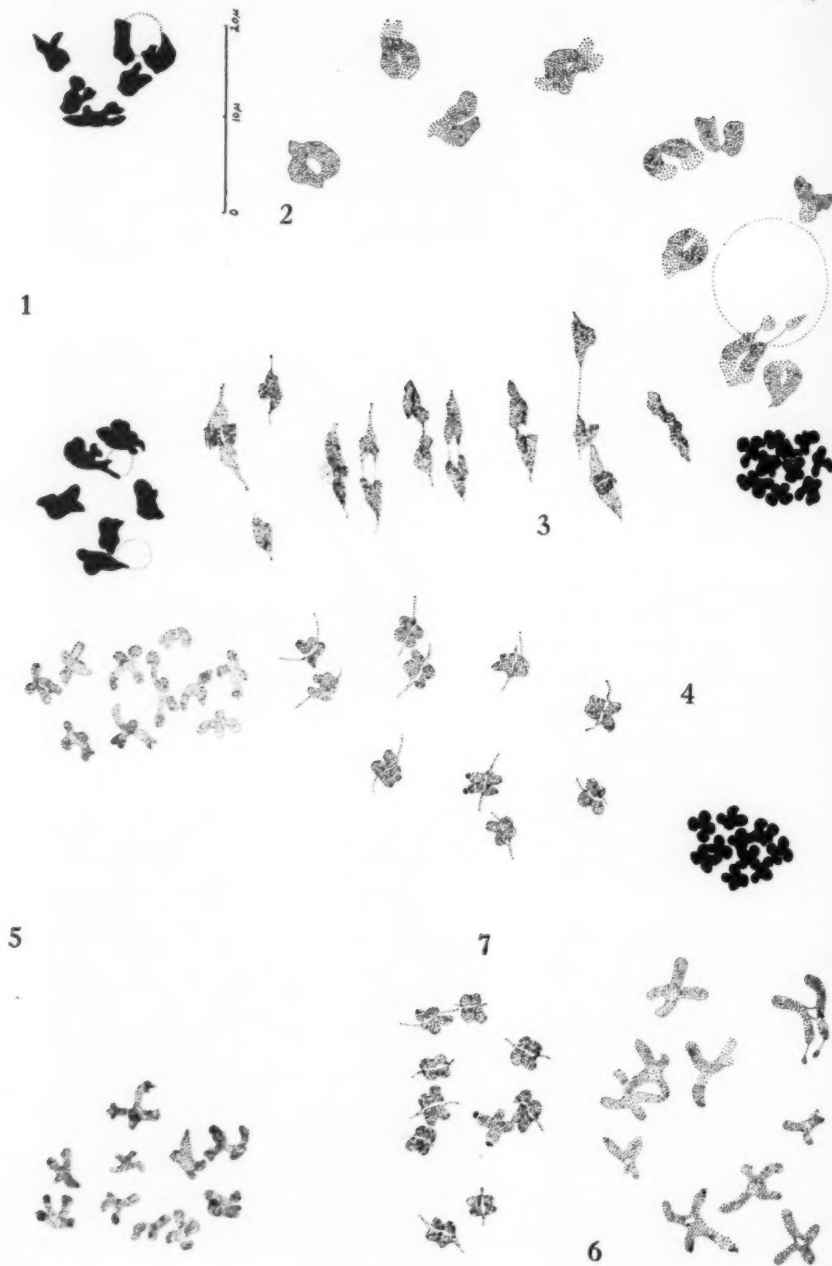
## EXPLANATION OF PLATE

## PLATE 10

- Fig. 1. *Coix poilanei* Mimeur. Showing twelve tapetal chromosomes in endoprophase.
- Fig. 2. *Coix poilanei*. Tapetal cell with tetraploid number of chromosomes undergoing a second endomitotic cycle.
- Fig. 3. *Polytoca macrophylla* Benth. Tapetal chromosomes in endoprophase.  $\times 1350$ .
- Fig. 4. *Polytoca macrophylla*. Tapetal chromosomes in endometaphase.  $\times 1350$ .
- Fig. 5. *Polytoca macrophylla*. Tapetal chromosomes in late endometaphase.
- Fig. 6. "Blue Adlay." Pachytene.  $\times 1350$ .
- Fig. 7. *Coix Lacryma Jobi* var. *typica*, from Coimbatore. Pachytene.  $\times 1350$ .



NIRODI—ASIATIC RELATIVES OF MAIZE



NIRODI—ASIATIC RELATIVES OF MAIZE

EXPLANATION OF PLATE

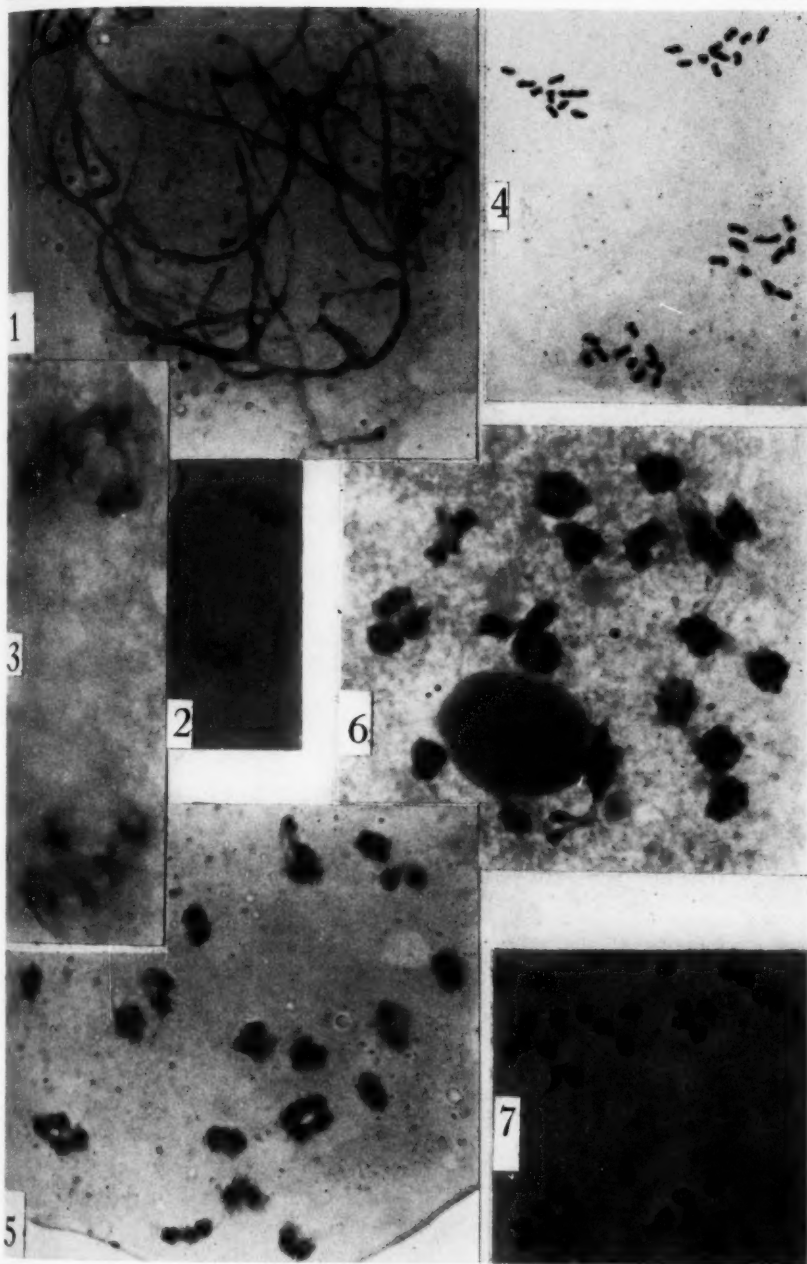
PLATE 11

- Fig. 1. *Coix poilanei* Mimeur. Telophase I of a 12-chromosome cell.
- Fig. 2. "Blue Adlay." Diakinesis.
- Fig. 3. "Blue Adlay." Anaphase I.
- Fig. 4. "Blue Adlay." Telophase I.
- Fig. 5. "Blue Adlay." Late Telophase I.
- Fig. 6. "Blue Adlay." Prophase II.
- Fig. 7. "Blue Adlay." Metaphase II.

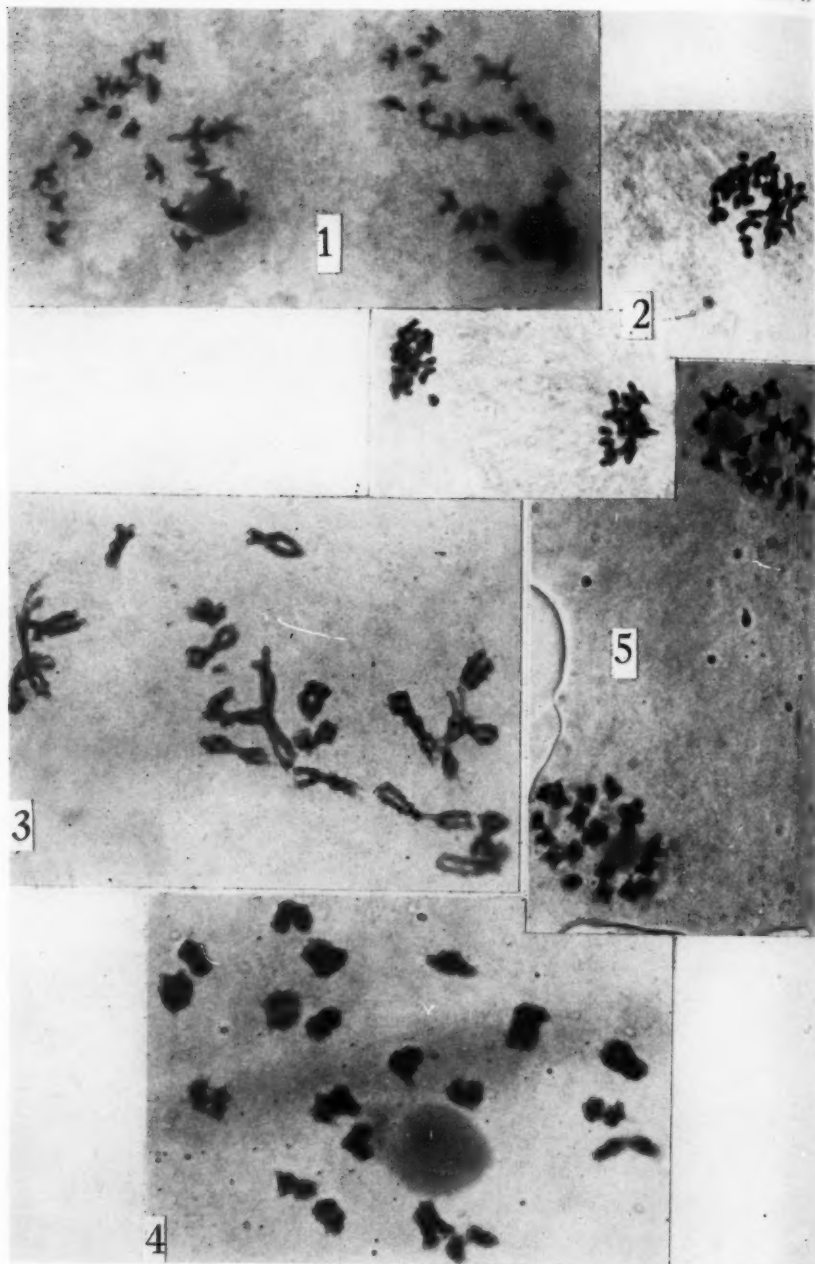
## EXPLANATION OF PLATE

## PLATE 12

- Fig. 1. *Coix gigantea* Koen. ex Roxb. Pachytene.  $\times 1350$ .  
Fig. 2. *Coix poilanei* Mimeur. Telophase I of normal 10-chromosome cell.  
Fig. 3. *Coix poilanei*. Prophase II.  $\times 1150$ .  
Fig. 4. "Blue Adlay." Telophase II.  
Fig. 5. *Coix gigantea*. Diakinesis showing ring formation.  $\times 1350$ .  
Fig. 6. *Coix gigantea*. Diakinesis showing satellite bivalent.  $\times 1800$ .  
Fig. 7. *Coix gigantea*. Anaphase I.  $\times 1350$ .



NIRODI—ASIATIC RELATIVES OF MAIZE

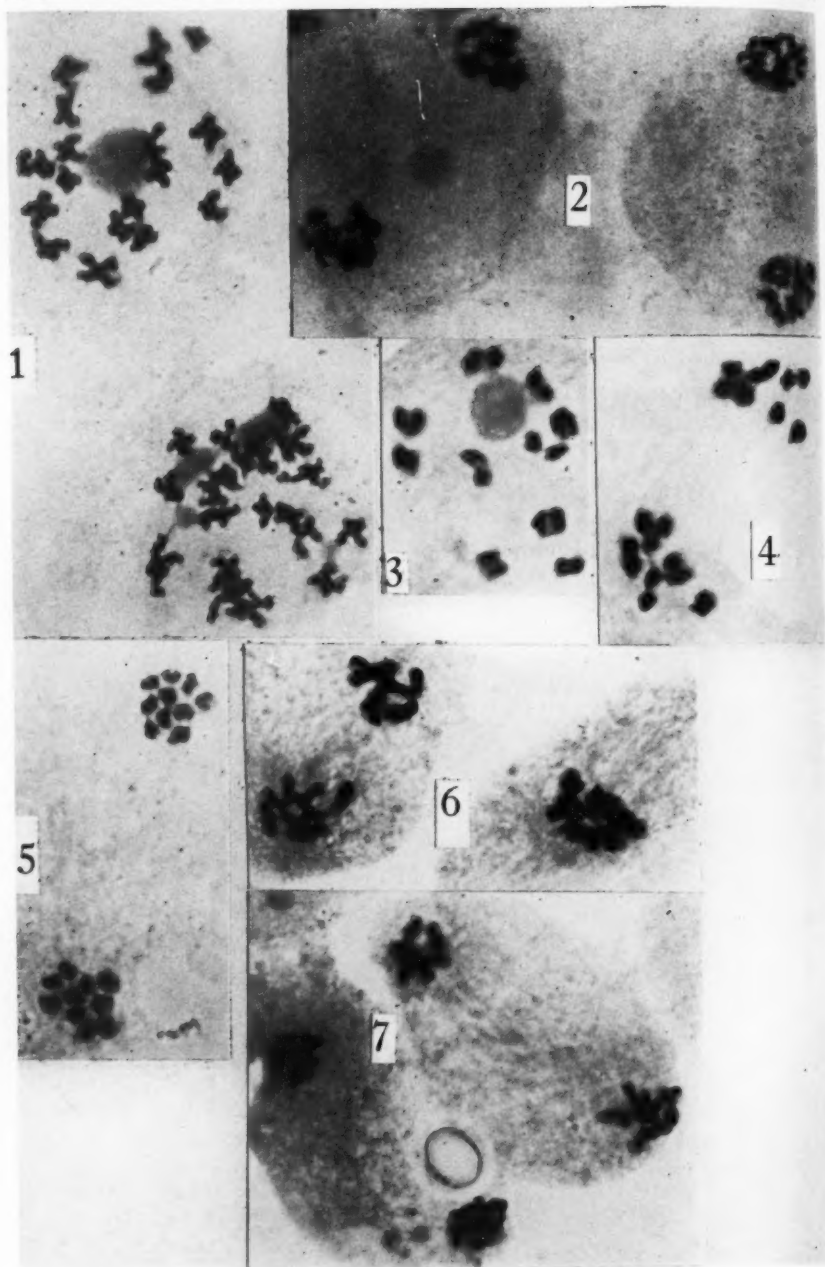


NIRODI—ASIATIC RELATIVES OF MAIZE

EXPLANATION OF PLATE

PLATE 13

- Fig. 1. *Coix gigantea* Koen. ex Roxb. Prophase II showing extra bodies.  $\times 990$ .  
Fig. 2. *Coix gigantea*. Anaphase II.  $\times 1170$ .  
Fig. 3. *Polytoca macrophylla* Benth. Diplotene.  $\times 875$ .  
Fig. 4. *Polytoca macrophylla*. Diakinesis.  $\times 1350$ .  
Fig. 5. *Polytoca macrophylla*. Telophase I.  $\times 1100$ .



NIRODI—ASIATIC RELATIVES OF MAIZE

EXPLANATION OF PLATE

PLATE 14

- Fig. 1. *Polytoca macrophylla* Benth. Prophase II.  $\times 1170$ .
- Fig. 2. *Polytoca macrophylla*. Telophase II.  $\times 800$ .
- Fig. 3. *Chionachne Koenigii* (Spreng.) Thwaites. Diakinesis.
- Fig. 4. *Chionachne Koenigii*. Anaphase I.
- Fig. 5. *Chionachne Koenigii*. Telophase I.
- Fig. 6. *Chionachne Koenigii*. Anaphase II.  $\times 1550$ .
- Fig. 7. *Chionachne Koenigii*. Telophase II.  $\times 1350$ .

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## LICHENOLOGICAL NOTES ON THE FLORA OF THE ANTARCTIC CONTINENT AND THE SUBANTARCTIC ISLANDS. I-IV

CARROLL W. DODGE  
AND EMANUEL D. RUDOLPH\*

In 1947-1948, the Australian National Antarctic Research Expedition established weather stations at Heard Island and Macquarie Island and somewhat later at Mawson in MacRobertson Land, on the Antarctic Continent. Through the kindness of Dr. H. W. Jessep of the National Herbarium, Melbourne Botanic Garden, and Dr. A. M. Gwynn, Medical Officer and Biologist of the Australian National Antarctic Research Expedition (A.N.A.R.E.), we have had the privilege of studying the lichen collections.

### I. ADDITIONS TO THE LICHEN FLORA OF HEARD ISLAND

Previous collections were reported by Dodge (1948) based on the British Australian New Zealand Antarctic Research Expedition (B.A.N.Z.A.R.E.), November 27-December 2, 1929, all between Atlas Cove and Corinthian Bay. The weather station was established at Atlas Cove in December 1947 (Scholes, 1951) and closed in 1955. The earlier collections received in 1949 were by D. Alan Gilchrist, Medical Officer; the collector of the later specimens was not recorded on the herbarium labels and are cited: A.N.A.R.E. The island was more accurately mapped in 1948 (A.N.A.R.E. 1949). Most of the southern part of the island is covered by glaciers and ice fields, so that the lichen collections have come from the northwestern part, especially the Cape Laurens peninsula on the northwest corner. Thirty-two species are represented, of which three are new and fifteen have not been previously reported although known from Kerguelen Island to the northwest, making a total of 52 species known from Heard Island.

*THELIDIUM HEARDENSE* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:44. 1948.

The thallus is lighter (vinaceous buff) than the type, but it agrees microscopically.

North of Cape Laurens on volcanic rock, A.N.A.R.E. 75.

*THELIDIUM PRAEVALESCENS* (Nyl.) Zahlbr., Deutsche Südpolar Exp. 8:51. 1906.

*Verrucaria praevalens* Nyl., in Crombie, Jour. Linn. Soc. Bot. 15:192. 1876.

As in most previous collections, all of our material is sterile although the thallus has a characteristic appearance.

West Bay, A.N.A.R.E. 743; north of Cape Laurens, on broken lava, in cave, A.N.A.R.E. 67, 72.

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Issued June 23, 1955.

*MICROGLAENA KERGUELENA* (Nyl.) Zahlbr., Deutsche Südpolar Exp. 8:51. 1906.

*Verrucaria kerguelena* Nyl., in Crombie, Jour. Bot. Brit. For. 14:22. 1876.

*D. Alan Gilchrist* 5, growing with *Steinera Werthii* Zahlbr. New to Heard Island.

*XANTHOPYRENIA heardensis* Dodge & Rudolph, n. sp.

Type: Heard Island, north of Cape Laurens at base of black cliffs, A.N.A.R.E. 76.

Thallus areolatus, areolis 0.3–0.5 mm. diametro subconvexis substipitatisque, marginibus liberis crenulatis, humectatis obscure flavo-viridibus, siccatis flavo-citrinis, homoeomericus; algae *Xanthocapsa*, coloniis sphaericis aut oblongis, vaginis flavo-brunneis, cellulis 7–8  $\mu$  diametro; hyphae 2–3  $\mu$  diametro inter colonias algarum.

Perithecia immersa, 1–3 in quaque areola, subsphaerica, 200–250  $\mu$  diametro, ostiolo minuto; parathecium obscure brunneum, 15–20  $\mu$  crassitudine, cellulis polyhedricis; asci 12–15  $\times$  115  $\mu$ , leptodermei; ascosporae octonae, imbricatum monostichae, late fusiformes, 19–24  $\times$  8–9  $\mu$ , tenui cum halone dum in asco, dein liberae 24  $\times$  10–11  $\mu$ , biloculares, cellula superiori majori, hyalinae, septo constrictae.

Thallus areolate, areoles 0.3–0.5 mm. in diameter, slightly convex above, substipitate below, margins free, crenulate, dark yellow-green when moist, old gold to buffy citrine when dry, homoeomeric; algae *Xanthocapsa*, colonies rounded to oblong, of 4–16 cells with a thick yellow-brown sheath at first, becoming densely packed in a homogeneous gel with abundant hyphae and cells more rounded, 7–8  $\mu$  in diameter, each with its own sheath about 2  $\mu$  thick; hyphae 2–3  $\mu$  in diameter, filling most of the interstices between the algal cells and colonies.

Perithecia immersed or nearly so, 1–3 per areole, showing as minute dark brown to black points; subspherical, about 200–250  $\mu$  in diameter, ostiole small; wall dark brown, 15–20  $\mu$  thick, of polyhedral cells; asci 115  $\times$  12–15  $\mu$ , thin-walled, 8-spored; ascospores imbricately monostichous, broad fusiform, 19–24  $\times$  8–9  $\mu$ , with a thin halo while still in the ascus, 24  $\times$  10–12  $\mu$  when free, bilocular, the upper cell larger, hyaline, slightly constricted at the septum.

*STEINERA GLAUCELLA* (Tuck.) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:66. 1948.

*Pannaria glaucella* Tuck., Bull. Torrey Bot. Club 6:57. 1875.

Growing with *Placopsis bicolor* (Tuck.) B. de Lesd., on broken lava, north of Cape Laurens, A.N.A.R.E. 80. New to Heard Island.

*STEINERA WERTHII* Zahlbr., Deutsche Südpolar Exp. 8:43. 1906.

*D. Alan Gilchrist* 5 and unnumbered specimen.

*LICHINA ANTARCTICA* Crombie, Jour. Bot. Brit. For. 14:21. 1876.

On crystalline rock (sandstone?), A.N.A.R.E. New to Heard Island.

? *SIPHULASTRUM CLADINOIDES* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:69. 1948.

We have doubtfully referred our material to this species. It forms compact hemispheric cushions up to 2.5 cm. in diameter. The habit resembles young dense tufts of *Sphaerophorus fragilis* Pers. from the Arctic and Subarctic but it is completely different in structure. The thalli are stiffer than in the type. Although the tips of the ultimate branches become very dark brown, we have been unable to find any reproductive structures. It may represent a new species.

North of Cape Laurens on broken lava, A.N.A.R.E. 78. New to Heard Island.

*COLLEMOPSIDIUM PYRENULOIDES* Dodge & Rudolph, n. sp.

Pl. 15, fig. 3.

Type: Heard Island, north of Cape Laurens, on humus in cave, A.N.A.R.E. 65.

Thallus gelifactus, flavidus, siccitate fragillimus, membrano-foliosus, semipellucidus, lobis irregularibus sinibus rotundatis, erectis, subrugosis; homoeomericus; algae Xanthocapsoidae, cellulis 5-6  $\mu$  diametro; hyphae sparsae, tenues.

Apothecia lecanorina immersa, 0.4-0.5 mm. diametro; amphithecium non bene evolutum; hypothecium ca. 25  $\mu$  crassitudine, hyphis periclinalibus intertextis; thecium 100  $\mu$  altitudine; paraphyses 3-4  $\mu$  diametro, pachydermae; asci clavati, juventute apice incrassati; ascospores octonae, brunneae, late fusiformes, biloculares, septo constrictae, pachydermae, 25-30  $\times$  10-14  $\mu$ .

Thallus a yellowish gel, very fragile when dry, yellow, foliose-membranous, semipellucid, lobes very irregular with somewhat rounded sinuses, erect, subrugose; homoeomericous; algae Xanthocapsoid, cells mostly singly dispersed in the gel without evident sheath, 5-6  $\mu$  in diameter, occasionally in small subspherical colonies up to 40  $\mu$  in diameter with thin sheaths about each cell and a somewhat thicker sheath surrounding the colonies, best seen in the amphithecium; hyphae very slender, not abundant; some bacterial colonies imbedded in the gel as well as a few moss (?) fragments.

Apothecia lecanorine, immersed or nearly so, about 0.4-0.5 mm. in diameter; amphithecium not clearly differentiated, a zone of Xanthocapsoid colonies with more abundant subvertical hyphae; hypothecium about 25  $\mu$  thick, of interwoven periclinal hyphae; paraphyses 3-4  $\mu$  in diameter with thick walls, occasionally branched; thecium 100  $\mu$  tall; asci clavate, thickened at the tip when young, diffluent, 8-spored; ascospores brown, broad, fusiform, sometimes flattened on one side, bilocular, constricted at the septum, wall thick, protoplasts rounded, rarely 2 distinct protoplasts in each cell, resembling the spores of *Pyrenula*, 25-30  $\times$  12-14  $\mu$ .

The thallus suggests the Pyrenopsidaceae, but the algal cells mostly occur singly without an evident sheath and the gel is much softer when moist so that we have been unable to secure good sections. It is possible that the fungus is a parasitic *Ticthothecium*, but the mycelium below the hypothecium is continuous with that of the thallus and it lacks a parathecium. Although *C. pyrenuloides* is foliose, it seems more closely related to *Collemopsidium* than to any other genus of the Pyrenopsidaceae.

North of Cape Laurens, on humus in cave, *A.N.A.R.E.* 64, type, 67 sterile.

*PANNARIA DICHROA* (Hook. f. & Tayl.) Crombie, Jour. Linn. Soc. Bot. 16:220. 1876.

*Lecanora dichroa* Hook. f. & Tayl., London Jour. Bot. 3:643. 1844.

Probably owing to the very rough surface of the lava, the lobes are somewhat ascendant and imbricate. The thallus is darker, light brownish olive and not stained with iron. On another very dense rock without locality, nearly covered by *Blastenia keroplasta* Zahlbr., the thallus is quite typical.

*D. Alan Gilchrist* 3; north of Cape Laurens on broken lava, *A.N.A.R.E.* 74.

*LECIDEA AUBERTI* B. de Lesd., Ann. Crypt. Exot. 4:99. 1931.

*D. Alan Gilchrist* 8.

*LECIDEA ASSENTIENS* Nyl., in Crombie, Jour. Bot. Brit. For. 13:334. 1875.

North of Cape Laurens, on volcanic rock, *A.N.A.R.E.* 75. New to Heard Island.

*LECIDEA SUBASSENTIENS* Nyl., in Crombie, Jour. Bot. Brit. For. 14:21. 1876.

*D. Alan Gilchrist* 4.

*RHIZOCARPON KERGUELENSE* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:116. 1948. Jacka Valley, on cliffs, *A.N.A.R.E.* 33.

*RHIZOCARPON MAWSONI* Dodge, B.A.N. Z.A.R.E. Rept. B. 7:115. 1948.

*D. Alan Gilchrist* 7. New to Heard Island.

*RHIZOCARPON JOHNSTONI* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:118. 1948.

On moraine of Schmidt Glacier, *A.N.A.R.E.* 242. New to Heard Island.

*CLADONIA PHYLLOPHORA* (Tayl.) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:132. 1948.

*Cenomyce phyllophora* Tayl. in Hook. f. & Tayl., London Jour. Bot. 3:652. 1844.

North of Cape Laurens, *A.N.A.R.E.* 70.

*CLADONIA JOHNSTONI* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:135. 1948.

Some podetia are nearly clothed with coarse granules, rarely almost isidioid, thus somewhat resembling *C. pyxidata* (L.) Fr.

Among mosses on broken lava, north of Cape Laurens, *A.N.A.R.E.* 69. New to Heard Island.

*ARGOPSIS CYMOSA* (Crombie) Stzbgr., Ber. Thätigk. St. Gall. Naturw. Ges. 1889-90:231. 1891.

*Stereocaulon cymosum* Crombie, Jour. Linn. Soc. Bot. 15:182. 1876.

On broken lava, north of Cape Laurens, *A.N.A.R.E.* 71. New to Heard Island.

*URECEOLINA KERGUELIENSIS* Tuck., Bull. Torrey Bot. Club 6:58. 1875.

Jacka Valley, 600 ft., on cliff, *A.N.A.R.E.* 34. New to Heard Island.

ASPICILIA LYGOMMA (Nyl.) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:164. 1948.

*Lecidea lygomma* Nyl. in Crombie, Jour. Bot. Brit. For. 13:334. 1875.

On boulders, 20 ft., West Bay, A.N.A.R.E. 743, growing with *Tbelidium praevalescens* (Nyl.) Zahlbr. and *Kuttlingeria crozetica* (Zahlbr.) Dodge. New to Heard Island.

ASPICILIA DISJUNGUENDA (Nyl.) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:167. 1948.

*Lecanora disjuguenda* Nyl. in Crombie, Jour. Bot. Brit. For. 15:105. 1877.

D. Alan Gilchrist 6, 7, 9.

ASPICILIOPSIS MACROPHTHALMA (Hook. f. & Tayl.) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:175. 1948.

*Urceolaria macrophthalma* Hook. f. & Tayl., London Jour. Bot. 3:640. 1844.

D. Alan Gilchrist 10.

PLACOPSIS BICOLOR (Tuck.) B. de Lesd. Ann. Crypt. Exot. 4:100. 1931.

*Placodium bicolor* Tuck., Bull. Torrey Bot. Club 6:57. 1875.

The specimens are much paler than usual, probably from less iron in the rocks, and cephalodia are very rare.

North of Cape Laurens, on broken lava, A.N.A.R.E. 80, growing with *Steinera glauccella* (Tuck.) Dodge; on cliff, Jacka Valley, 600 ft., A.N.A.R.E. 31.

USNEA TAYLORI Hook. f., London Jour. Bot. 3:657. 1844.

Moraine of Baudessen Glacier, 800 ft., A.N.A.R.E. 250. New to Heard Island.

USNEA INSULARIS (Lamb) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:211. 1948.

*Neurospogon insularis* Lamb, Jour. Linn. Soc. Bot. 52:215. pl. 8, fig. 17. 1939.

Only a few plants, beginning to form cupulate apothecia.

Mt. Aubert de la Rüe, 300 ft., A.N.A.R.E. 4.

USNEA TRACHYCARPA (Stirton) Müll. Arg. Nuovo Giorn. Bot. Ital. 21:37. 1889.

*Neurospogon trachycarpus* Stirton, Scottish Nat. 6:105. 1881.

D. Alan Gilchrist 2. New to Heard Island.

BLASTENIA KEROPLASTA Zahlbr., Deutsche Südpolar Exp. 8:28. 1906.

Two specimens without locality, A.N.A.R.E. New to Heard Island.

KUTTLINGERIA CROZETICA (Zahlbr.) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:226. 1948.

*Caloplaca crozetica* Zahlbr., Deutsche Südpolar Exp. 8:29. 1906.

Atlas Cove, on rocks above high water, A.N.A.R.E. 225; West Bay, 20 ft., A.N.A.R.E. 743; on cliff in Jacka Valley, 600 ft., A.N.A.R.E. 32; D. Alan Gilchrist 1. New to Heard Island.

BUELLIA SUBPLICATA (Nyl.) Müll. Arg., Bot. Jahrb. [Engler] 5:138. 1884.

*Lecidea subplicata* Nyl. in Crombie, Jour. Bot. Brit. For. 13:334. 1875.

On cliff, Jacka Valley, A.N.A.R.E. 33.

RINODINA ASPICILINA Zahlbr., Deutsche Südpolar Exp. 8:50. 1906.

Two small specimens without locality, A.N.A.R.E.

#### DEUTEROLICHENES (LICHENES IMPERFECTI)

Occasionally lichenologists have encountered conidial fructifications on lichen thalli, sometimes associated with apothecia, sometimes not. Müller-Argau (1881) described an otiform conidial structure which he named a campylidium. Vainio (1890) found the same structure on a thallus of *Lopadium perpallida* (Nyl.) Zahlbr. (*Lecidea perpallida* Nyl.) and referred it to *Cyphella aeruginascens* Karst. Spegazzini (1909) named it as a genus of lichenes imperfecti, *Chlorocyphella*, based on *C. subtropica* Speg. Keissler (1927) transferred *Cyphella aeruginascens* Karst. and described several new varieties. Mameli Calvino (1930) proposed the name Deuterolichenes to include *Chlorocyphella*, and Cengia Sambo (1937, 1941) and Rizzini (1952) have reported species of *Chlorocyphella* not associated with apothecia. Malme (1935) considered *C. aeruginascens* (Karst.) Keissl. to be a conidial stage of *Lopadium perpallidum* (Nyl.) Zahlbr., and Dodge (1953) described a campylidium as a conidial state of *L. Deightoni* Dodge. Campylidia have also been observed on *Sporopodium* sp.

Müller-Argau (1890) described another type of fructification, the orthidium, which resembles an apothecium except that the thecium is replaced by conidiophores, and the senior author has seen a similar fructification on a foliicolous thallus from Jamaica. Our material contains an orthidium-bearing lichen from Heard Island, resembling *Ephelis* Fr. of the Excupulaceae, which has unicellular spores, while those of our lichen become septate as do those of *Ephelis trinitensis* Cooke & Massee, the imperfect state of *Balsania trinitensis* Cooke & Massee on *Panicum palmifolium* in Trinidad, B.W.I.

#### EPHELIDIUM Dodge & Rudolph, n. gen.

Type: *Ephelidium beardense* Dodge & Rudolph.

Thallus crustosus, indeterminatus, sorediosus, ecorticatus, heteromericus; algae protococcoideae. Orthidium sessile, concavum, margine persistente; conidiophorae simplices; conidia singulatim disposita, terminalia, acicularia, septata.

Thallus crustose, indeterminate, sorediose, ecorticate, heteromericus; algae protococcoid. Orthidium sessile, concave with a persistent margin, resembling a lecanorine (or biatorine as the algae die above) apothecium; conidiophores unbranched; conidia single, terminal, acicular, long remaining unicellular but finally multiseptate.

*EPHELIDIUM beardense* Dodge & Rudolph, n. sp.

Pl. 15, fig. 1.

Type: Heard Island, Atlas cove at foot of *Poa* mound, A.N.A.R.E. 147.

Thallus crustosus, indeterminatus, 0.7–1.2 mm. crassitudine, citrinus, sorediosus; ecorticatus; stratum algarum ca. 280  $\mu$  crassitudine, cellulis protococcoideis, 8.7–12.2  $\mu$  diametro; medulla crassa, hyphis 1  $\mu$  diametro dense intertextis, nubilatis.

*Orthidium sessile*, basi constrictum, orbiculare, 0.6–1.5 mm. diametro, sub-ochraceum, margine 250–280  $\mu$  crassitudine; conidiophorae tenues, unicellulares, 13–17  $\mu$  longitudine; conidia singulatim disposita, acicularia, hyalina, 30–44  $\times$  2  $\mu$ , primum unicellulares, dende ad 7-septata, recta aut subcurvata.

Thallus crustose, indeterminate, 0.7–1.2 mm. thick, buffy citrine, sorediose, K orange brown, C—; ecorticate; algal layer about 280  $\mu$  thick, cells protococcoid, spherical to somewhat polyhedral from mutual pressure, 8.7–12.2  $\mu$  in diameter; medulla thick, of closely woven hyphae about 1  $\mu$  in diameter, somewhat nubilated with granules and including pieces of roots etc. from the substrate.

*Orthidium sessile*, constricted at the base, circular, 0.6–1.5 mm. in diameter, ochraceous buff, disc very concave; margin 250–280  $\mu$  thick, finally undulate; algae in a discontinuous layer on the outside of the layer of conidiophores, tending to die out above and forming a continuous layer below; the medulla around and between the algal colonies is formed of compactly woven hyphae about 1  $\mu$  in diameter; conidiophores arising from the medullary hyphae, forming a continuous layer 13–17  $\mu$  thick; conidia borne singly, acicular, 30–44  $\times$  2  $\mu$ , hyaline, non-septate until late, finally up to 7-septate, straight or slightly curved, slightly tapering at the ends.

## II. ADDITIONS TO THE LICHEN FLORA OF MACQUARIE ISLAND

Previous collections were reported by Dodge (1948). Most of the present collections are from the northern half of the island, collected mostly by Norman R. Laird and by N. M. Haysom of the A.N.A.R.E. Taylor (1954) has discussed the problem of distribution of the flowering plants which apparently have much wider ranges than the lichens. Twenty-seven species are reported from the present collection, three of which are new and three not previously reported bringing the total species of lichens to forty-four. Several other possible new species will be reported in a later number of these Lichenological Notes. In the following list *MI/49/* has been omitted from N. M. Haysom's numbers of collections.

*MICROTHELIA MACQUARIENSIS* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:48. 1948. Plateau, 800 ft., between Mt. Elder and Sandy Bay, N. M. Haysom Z8.

*COENOGONIUM SUBTORULOSUM* Müll. Arg., Jour. Linn. Soc. Bot. 32:207. 1896. Orange red when fresh, drying olive buff. The *Trentepohlia* filaments have very few corticating hyphae. From glacial moraine above Sandy Bay, 500 ft., N. M. Haysom Z2.

*PSOROMA VERSICOLOR* (Hook. f. & Tayl.) Müll. Arg., Flora 71:538. 1888.

*Lecanora versicolor* Hook. f. & Tayl., London Jour. Bot. 3:642. 1844, non Ach.

The squamules are less well developed than in previous collections but the apothecia agree microscopically.

Norman R. Laird 2, 2a, 2c; Featherbed Terrace, growing over decaying hepatics and other vegetable debris, A.N.A.R.E.

*Pseudocypbellaria glabra* (Hook. f. & Tayl.) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:79. 1948.

*Stricta glabra* Hook. f. & Tayl., London Jour. Bot. 3:647. 1844.

South end of Plateau, on moss, *N. M. Haysom* Z114; north end of Plateau, on soil and over decaying mosses, *Norman R. Laird*; Featherbed Terrace, A.N.A.R.E.; Wireless Hill, *N. M. Haysom* Z1; north of Lusitania Bay, *N. M. Haysom* Z134.

*PELTIGERA Lairdi* Dodge & Rudolph, n. sp.

Type: Macquarie Island, growing on soil over decaying grasses, mosses and hepatics, *Norman R. Laird* 4, A.N.A.R.E.

Thallus foliosus, in herbario isabellinus, ad 10 cm. diametro, 400  $\mu$  crassitudine, lobis sterilibus ca. 1.5 cm. latitudine, 2 cm. longitudine; tomentum crassum, verrucosum in partibus junioribus; superficies inferior arachnoideus inter venas; venae sparsae, elevatae, arachnoideo-tomentosae, rhizinis simplicibus vel semel dichotome ramosis, ca. 5 mm. longitudine, concoloribus; cortex ca. 90  $\mu$  crassitudine, pseudoparenchymaticus, cellulis 12–15  $\mu$  diametro leptodermeis; stratum algarum 50–55  $\mu$  crassitudine, cellulis nostocaceis, 5  $\mu$  diametro; medulla 270  $\mu$  crassitudine, hyphis periclinalibus pachydermeis, 4  $\mu$  diametro, parte superiore compacta, inferiore laxiore, hyphis ad 8  $\mu$  diametro, lumine 5  $\mu$ .

Apothecia in lobis erectis non revolutis, 15 mm. altitudine, 5–6 mm. latitudine, sita; discus nigro-brunneus, 4 mm. diametro; sine amphithecio nec parathecio, stratum algarum sub hypothecio crassiore, ad 120  $\mu$  crassitudine; hypothecium 30  $\mu$  crassitudine, brunneum, superne obscurius, pseudoparenchymaticum, hyphis periclinalibus; thecium 120–130  $\mu$  altitudine; paraphyses simplices, ca. 2  $\mu$  diametro; asci 100–105  $\times$  11–12  $\mu$ , juventute apice incrassati; ascosporae octonae, hyalinae, aciculares, multiseptatae, ca. 56  $\times$  3  $\mu$ .

Thallus foliose, becoming isabella color in the herbarium, up to 10 cm. in diameter, 400  $\mu$  thick, margin lobed, sterile lobes about 1.5 cm. wide and 2 cm. long, somewhat lacerate on drying, ends of lobes with thick, verrucose tomentum above, becoming smooth but surface dull in the older portions as the tomentum weathers away; underside pinkish buff, arachnoid between the sparse veins; veins elevated, arachnoid-tomentose; rhizinae not abundant, simple or once-dichotomous near the tips, about 5 mm. long, concolorous; cortex about 90  $\mu$  thick, pseudoparenchymatous, cells rather thin-walled, 12–15  $\mu$  in diameter; algal layer 50–55  $\mu$  thick, of *Nostoc* colonies, cells about 5  $\mu$  in diameter in an inconspicuous gel; medulla 270  $\mu$  thick, of closely packed periclinal hyphae, thick-walled, about 4  $\mu$  in diameter, less compact and more irregularly arranged below, forming the arachnoid underside with hyphae up to 8  $\mu$  in diameter, lumen 5  $\mu$ .

Apothecia on erect lobes, not revolute, 15 mm. tall, 5–6 mm. wide, disc very dark brown, 4 mm. in diameter; no amphithecium nor parathecium differentiated; algal layer thicker below the hypothecium, up to 120  $\mu$  thick; hypothecium 30  $\mu$  thick, lower half pale brown, upper half very dark brown, pseudoparenchymatous from periclinal hyphae; thecium 120–130  $\mu$  tall; paraphyses about 2  $\mu$  in diameter, unbranched, tips ending in the dark brown epithelial gel; asci 100–105  $\times$  11–12  $\mu$ ,

tips slightly thickened when young, 8-spored; ascospores hyaline, acicular,  $56 \times 3 \mu$ , thin-walled, many septate.

This species somewhat resembles *Peltigera dilacerata* Gyelnik from Auckland, New Zealand, which has longer and narrower lobes with dilacerate margins and is about half as thick.

LECIDEA SUBGLOBULATA Knight, Trans. Proc. N. Zeal. Inst. 8:314. 1875 [1876].

South slopes of Wireless Hill, A.N.A.R.E. New to Macquarie Island.

CATILLARIA (EUCATILLARIA) *Rudolphi* Dodge, n. sp.

Type: Macquarie Island, without locality, but the rock types closely resemble those from the south slopes of Wireless Hill, A.N.A.R.E.

Thallus crustosus, albidus, continuus aut ad centrum areolatus crassior, margine irregulariter lobatus; cortex fastigiatus subdecompositus, erosus, ad  $30 \mu$  crassitudine; stratum algarum  $65 \mu$  crassitudine, cellulis protococcoideis  $6-8 \mu$  diametro; medulla  $250-300 \mu$  crassitudine, hyphis tenuibus, granulis brunneis nubilatis, dense contexta.

Apothecia subimmersa aut sessilia, ad 2.5 mm. diametro, orbicularia, aut mutua pressione angularia, margine elevato, disco plano aut subconvexo nigro; parathecium carbonaceum, in margine  $50 \mu$  crassitudine ad  $125-160 \mu$  sub thecio; hypothecium non bene evolutum; thecium  $90-120 \mu$  altitudine; paraphyses tenues, septatae, super ascos ramosae, apicibus clavatis brunneis, ca.  $1.5 \mu$  diametro; asci  $50-60 \times 7-8.5 \mu$ , cylindrico-clavati, leptodermei; ascosporae octonae, hyalinae, biloculares, uniseriales, ellipsoideae,  $13-15 \times 6-7 \mu$ .

Thallus whitish, sometimes stained ferruginous from iron in the underlying rock, thin, continuous at the margin, thicker toward the areolate center, K yellow then orange, margin irregularly lobate, distinct; cortex fastigiate, somewhat decomposed and eroded, up to about  $30 \mu$  thick; algal layer  $65 \mu$  thick, cells protococcoid,  $6-8 \mu$  in diameter in a continuous dense layer; medulla  $250-300 \mu$  thick, of densely woven slender hyphae, heavily nubilated with dark brown granules.

Apothecia slightly immersed to sessile, up to 2.5 mm. in diameter, abundant, circular or angular from mutual pressure, margins elevated, disc plane to slightly convex, black; parathecium carbonaceous,  $50 \mu$  thick at the margin,  $125-160 \mu$  thick below the thecium; hypothecium not clearly differentiated; thecium  $90-120 \mu$  tall; paraphyses slender, septate, branched at the level of the tips of the asci, tips slender, clavate, brownish, about  $1.5 \mu$  in diameter, asci  $50-60 \times 7-8.5 \mu$ , cylindric-clavate, thin-walled, 8-spored; ascospores hyaline, bilocular, mostly uniseriate, ellipsoidal,  $13-15 \times 6-7 \mu$ .

The germinating ascospore produces an extensive black hypothallus. As contact is made with algal cells, thin assimilative areoles develop and finally fuse, covering the hypothallus as a continuous thallus which gradually thickens with age.

Without locality but probably from south slopes of Wireless Hill, A.N.A.R.E., type; west side of Wireless Hill, N. M. Haysom Z152; south end of Plateau, N. M.

*Haysom* Z137; Plateau, 900 ft., young, A.N.A.R.E.; north end of Plateau, N. M. *Haysom* Z86; without locality, Norman R. Laird 8.

CLADIA AGGREGATA (Sw.) Nyl., Bull. Soc. Linn. Normand. II, 4:167. 1870.  
*Lichen aggregatus* Sw., Nova Gen. Sp. Pl. Ind. Occ. 147. 1788.  
West coast, fluviatile swamp, 50 ft., A.N.A.R.E.

CLADONIA FLORIFORMIS Dodge, B.A.N.Z.A.R.E. Rept. B. 7:134. 1948.  
Wireless Hill, 300 ft., Norman R. Laird 1d; Nuggets Creek, Norman R. Laird 1a, 1b, young; without locality, Norman R. Laird 1; only a few young plants among mosses, A.N.A.R.E. 5c.

CLADONIA MAWSONI Dodge, B.A.N.Z.A.R.E. Rept. B. 7:128. 1948.  
Nuggets Valley, 100 ft., A.N.A.R.E.; ? primary thallus only, mouth of cave, south end of isthmus, A.N.A.R.E.

CLADONIA SARMENTOSA (Tayl.) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:129. 1948.  
*Cenomyce sarmentosa* Tayl. in Hook. f. & Tayl., London Jour. Bot. 3:651. 1844.

Interior of cave, 35 ft., A.N.A.R.E.; near Brothert Point, 250 ft., A.N.A.R.E.; near Nuggets Creek, Norman R. Laird 1c, 1d, 2c; Lusitania Valley, east coast, 150 ft., A.N.A.R.E.

STEREOCAULON ARGODES Nyl., Compt. Rend. Acad. Sci. [Paris] 83:88. 1876.  
*Stereocaulon Argus* Th. Fr., Nova Acta R. Soc. Sci. Upsal. III, 2<sup>1</sup>:333. 1858; Hook. f. & Tayl., London Jour. Bot. 3:653. 1844, pro parte min.

For discussion of nomenclature, see Dodge (1948, pp. 142-144) sub *Argopsis megalospora*. In the present collection the dimensions of the ascospores are somewhat greater,  $45-53 \times 5.5-7 \mu$ , than those given by Th. M. Fries and Nylander.

On coastal vegetation north of Lusitania Bay, N. M. *Haysom* Z128; Plateau, N. M. *Haysom* Z1.

STEREOCAULON PULVINARE Dodge, B.A.N.Z.A.R.E. Rept. B. 7:139. 1948.  
Near Nuggets Creek, Norman R. Laird.

STEREOCAULON SUBMOLLESCENS Nyl., Compt. Rend. Acad. Sci. [Paris] 83:88. 1876.

Featherbed Terrace, A.N.A.R.E.; north end of Plateau, N. M. *Haysom* Z85.

PERTUSARIA TYLOPLACA Nyl. Compt. Rend. Acad. Sci. [Paris] 83:90. 1876.  
South end of Plateau, N. M. *Haysom* Z122; Plateau, 900 ft., A.N.A.R.E.; north end of Plateau, N. M. *Haysom* Z59, Z62; growing over *Menegazzia circumscordata* Santesson on radio mast erected by A.A.E. in 1911 on Wireless Hill, A.N.A.R.E.

PLACOPSIS PERRUGOSA (Nyl.) Nyl., Lich. Nov. Zelandiae, 57. 1888.

*Lecanora perrugosa* Nyl., Flora 48:338. 1865.

For complete description, see I. M. Lamb, Lilloa 13:268-272. 1947.

On rocky banks of Lusitania Creek, N. M. Haysom 2123. New to Macquarie Island.

*THAMNOLECANIA macquariensis* Dodge & Rudolph, n. sp.

Type: Macquarie Island, Wireless Hill, on cliff subject to water seepage, A.N.A.R.E.

Thallus fruticosus erectus aut subdecumbens, pulvinos hemisphaericos ad 3 cm. diametro formans, di- aut tri-chotome ramosus, torulosus, cinnamomeo-alutaceus, inferne ad 0.8 mm. diametro, superne tenuior, ad 1 cm. altitudine; ecorticatus; algae flavo-virides, cellulis sphaericis vel mutua pressione polyhedricis, 8–11  $\mu$  diametro; hyphae medullares ca. 3  $\mu$  diametro, conglutinatae, inter cellulas algarum.

Apothecia ad 1 mm. diametro in lateribus ramorum sessilia, plana dein convexa emarginataque, ca. 250  $\mu$  altitudine, disco nigro; amphithecium 250  $\mu$  crassitudine; parathecium non bene distinctum, margine ad 40  $\mu$  crassitudine; hypothecium obconicum, ca. 190  $\mu$  altitudine, hyphis verticalibus nigro-brunnei; thecium 135  $\mu$  altitudine; paraphyses 2.5–3  $\mu$  diametro, septatae, cellula terminali clavata  $4 \times 5.5 \mu$ , pachyderma nigro-brunnea; asci ca.  $65 \times 12 \mu$ , clavati, juventute apice incrassati; ascospores octonae, subdistichae in ascis  $16 \times 8 \mu$ , biloculares, brunneae, septo tenui constrictae, liberatae,  $12 \times 6 \mu$ , nigro-brunneae.

Thallus fruticose, erect or subdecumbent, forming dense, depressed hemispheric cushions up to 3 cm. in diameter, branching di- or trichotomous, torulose, pinkish buff to cinnamon buff, up to 0.8 mm. in diameter below, more slender above, circular in cross-section, about 1 cm. tall; ecorticate; algae yellow-green, spherical or somewhat polyhedral from mutual pressure in the outer portion, 8–11  $\mu$  in diameter with a thick sheath of periclinal medullary hyphae, more scattered throughout the medulla; hyphae about 3  $\mu$  in diameter, compact and conglutinate between the algal cells.

Apothecia up to 1 mm. in diameter, sessile on the sides of the branches, not on the ultimate branches, flat at first becoming convex and emarginate, about 250  $\mu$  tall, disc black; amphithecium about 250  $\mu$  thick, similar in structure to that of the thallus but the medullary hyphae more vertical; parathecium not well differentiated, about 40  $\mu$  thick at the margin, scarcely differentiated from the paraphyses, continuous below with the dark brown obconic hypothecium about 190  $\mu$  tall at the center, of vertical dark brown hyphae, not sharply differentiated from the thecium above; thecium 135  $\mu$  tall; paraphyses 2.5–3  $\mu$  in diameter, septate, terminal cell broadly clavate, about  $4 \times 5.5 \mu$ , thick-walled, dark brown above; asci about  $65 \times 12 \mu$ , clavate, tips very thick when young, 8-spored; ascospores subdistichous,  $16 \times 8 \mu$ , bilocular, brown, ellipsoid, slightly constricted at the thin septum, shrinking to  $12 \times 6 \mu$  when free from the ascus and very dark brown.

The specimens have been cut from the underlying rock, but the cut ends suggest that the base may expand into a circular holdfast. The systematic position of this species is not clear. The bilocular brown spores with a thin septum, the paraphyses and lecanorine apothecium suggest *Rinodina* sect. *Beltraminia*; the very dark hypothecium suggests *Melanaspicilia* Vainio. From both of these it differs in

its fruticose thallus. The structures of the thallus and of the apothecia are wholly different from those of the fruticose species of *Anaptychia*, but do resemble those of *Thamnolecania* from which it differs in a very dark brown hypothecium and broader brown bilocular spores. Its yellowish green algae suggest a relationship to *Thelidea* Hue, which is foliose with biatorine apothecia and hyaline ascospores. It is not a parasite as the medullary hyphae are continuous with those at the base of the hypothecium and the amphithecium is well developed; hence it cannot be considered a *Karschia* sp. on a *Siphula*.

PARMELIA TURGIDULA Bitter, Hedwigia 40:246. 1901.

Featherbed Terrace, over mosses. A single sterile plant. New to Macquarie Island but previously known from New Zealand.

PARMELIA SUBLUGUBRIS Dodge, B.A.N.Z.A.R.E. Rept. B. 7:188. 1948.

Featherbed Terrace, A.N.A.R.E.; Norman R. Laird 3; north end of Plateau, N. M. Haysom Z61.

PARMELIA TENUIRIMA Hook. f. & Tayl., London Jour. Bot. 3:645. 1844.

Featherbed fluvial terrace on northwest slopes, growing over mosses, Norman R. Laird; from rock face, Half Moon Bay, west coast, A.N.A.R.E.

MENEGAZZIA CIRCUMSOREDIATA Santesson, Ark. f. Bot. 30:11:14. 1942.

Thallus 9 cm. in diameter. Wireless Hill, on radio mast erected by the A.A.E. in 1911, A.N.A.R.E.; coastal rocks north of Lusitania Bay, N. M. Haysom Z127.

USNEA ARIDA v. MUSCICOLA Dodge, B.A.N.Z.A.R.E. Rept. B. 7:207. 1948.

Wireless Hill, on planks of A.A.E. radio hut, N. M. Haysom Z53.

USNEA CONTEXTA Motyka, Lich. Gen. Usnea Stud. Monog. 2:436. 1937.

Featherbed Terrace, A.N.A.R.E.; north end of Plateau, N. M. Haysom Z83.

USNEA TORULOSA (Müll. Arg.) Zahlbr., Cat. Lich. Univ. 6:594. 1930.

*Usnea dasygoides* f. *torulosa* Müll. Arg., Flora 66:19. 1883.

Our plants are only 3 cm. tall with shorter lower internodes. North of Lusitania Bay, N. M. Haysom Z130.

USNEA XANTHOPOGA Nyl., Compt. Rend. Acad. Sci. [Paris] 83:89. 1876.

Among mosses, Norman R. Laird 5a, 5b, 5c, 5d, 5e; Featherbed Terrace, very young, A.N.A.R.E.

RAMALINA GENICULATA Hook. f. & Tayl., London Jour. Bot. 3:665. 1844.

Turf from rock surface, west coast, 50 ft., A.N.A.R.E.; Featherbed Terrace, A.N.A.R.E.

GASPARRINIA MACQUARIENSIS Dodge, B.A.N.Z.A.R.E. Rept. B. 7:234. 1948.

One plant has much larger apothecia, up to 4 mm. in diameter, with flat discs and nearly excluded margins but agrees microscopically.

Hasselborough Bay, isthmus beach, Norman R. Laird 8a; beach of Garden Cove, N. M. Haysom Z11, Z223; Green Gorge, N. M. Haysom Z102.

*BUELLIA MAWSONI* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:243. 1948.  
South end of Plateau, *N. M. Haysom* Z137.

### III. FLORA OF ADÉLIE LAND

A small collection was received from Cape Margerie, 66° 50' S., 141° 20' E., collected on November 4, 1950, the first specimens taken from Adélie Land. Since the collection is small and Adélie Land lies between King George V Land and Queen Mary Land, it is not surprising that all these species have been reported before.

*UMBILICARIA HUNTERI* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:148. 1948.  
A.N.A.R.E. 4. Previously known from King George Land.

*ALECTORIA CONGESTA* (Zahlbr.) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:195. 1948.  
*Parmelia pubescens* v. *congesta* Zahlbr., Deutsche Südpolar Exp. 8:52. 1906.  
A.N.A.R.E. 3. Previously known from King George V Land to MacRobertson Land.

*USNEA ANTARCTICA* DuRietz, Svensk Bot. Tidskr. 20:90, 93. 1926.  
A.N.A.R.E. 6. Previously known from Marie Byrd Land to King George V Land.

*USNEA PUSTULATA* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:203. 1948.  
A.N.A.R.E. 5a. Previously known from King George V Land and Queen Mary Land.

*USNEA SCABRIDULA* (Lamb) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:204. 1948.  
*Neurospogon acromelanus* v. *inactivus* f. *scabridulus* Lamb, Jour. Linn. Soc. Bot. 52:220. 1939.  
A.N.A.R.E. 5. Previously known from South Victoria Land to King George V Land.

*XANTHORIA MAWSONI* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:236. 1948.  
A.N.A.R.E. 1. Previously known from King George V Land to MacRobertson Land.

*RINODINA FRIGIDA* (Darb.) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:259. 1948.  
*Buellia frigida* Darb., Brit. Nat. Antarct. "Discovery" Exp. Nat. Hist. 5:Lich.:7. 1910.

A.N.A.R.E. 3. Previously known from Marie Byrd Land to MacRobertson Land.

### IV. ADDITIONS TO THE FLORA OF MACROBERTSON LAND

Previous collections from Cape Bruce were reported by Dodge (1948). The present collections are from the A.N.A.R.E. weather station at Mawson, about 67° S. and 50° E., collected by the Medical Officer, Dr. A. M. Gwynn. Fourteen species are represented, one new species, six others new to MacRobertson Land,

making twenty-four species so far known. The Verrucariaceae are still absent from collections.

*HEPPIA ANTARCTICA* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:71. 1948.

Small sterile thalli along with several genera of Myxophyceae on a weathered crystalline rock with *Parmelia Johnstoni* Dodge, A. M. Gwynn Li23.

*LECIDEA HARRISSONI* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:101. 1948.

On rock with *Alectoria congesta* (Zahlbr.) Dodge, A. M. Gwynn Li29.

*UMBILICARIA SPONGIOSA* v. *SUBVIRGINIS* (Frey & Lamb) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:148. 1948.

*Umbilicaria antarctica* v. *subvirginis* Frey & Lamb, Trans. Brit. Myc. Soc. 22:272. 1939.

Thallus about 7 cm. in diameter, upper surface pale smoke-gray or lighter, very minutely rimulose.

A. M. Gwynn Li30. New to MacRobertson Land.

*UMBILICARIA SUBCEREBRIFORMIS* Dodge, B.A.N.Z.A.R.E. Rept. B. 7:149. 1948.

A. M. Gwynn Li30. New to MacRobertson Land.

*ACAROSPORA* (*PACHNOLEPIA*) *Gwynni* Dodge & Rudolph, n. sp.

Pl. 15, fig. 2.

Type: MacRobertson Land, Mawson, on weathered reddish granite? A. M. Gwynn Li21.

Thallus cerebriformis subfruticulosus, juventute citrinus dein magis olivaceo-  
viridis, ad 3 mm. diametro, substipitatus, marginibus liberis, ca. 500  $\mu$  crassitudine,  
inferne alutaceus; cortex superne 20–25  $\mu$  inferne ad 30  $\mu$  crassitudine, fastigiatus,  
pseudoparenchymaticus, cellulis pachydermeis, luminibus 2.5  $\mu$  diametro, strato  
amorpho gelifacto 15  $\mu$  crassitudine tectus; algae protococcoideae, cellulis 13–14  $\mu$   
diametro; medulla non distincte evoluta, hyphis 2  $\mu$  diametro.

Apothecia ca. 0.5 mm. diametro, orbicularia vel mutua pressione elliptica, im-  
mersa, disco obscuro; parathecium hyalinum, 15  $\mu$  crassitudine in lateribus thecii,  
subtus 25–30  $\mu$  crassitudine, hyphis periclinalibus; hypothecium 15  $\mu$  crassitudine,  
hyphis tenuibus grumosis dense contextum; thecium 230  $\mu$  altitudine; paraphyses  
cohaerentes, distinctae, pachydermeae, 2  $\mu$  diametro; asci 100  $\times$  20  $\mu$ , juventute  
apice incrassati; ascospores multae, ellipsoideae, ca. 3.5  $\times$  1.8  $\mu$  (liberae non visae).

Spermogonia immersa, 200  $\mu$  diametro; perifulcrum hyalinum, 15  $\mu$  crassi-  
tudine, hyphis pachydermeis, periclinalibus conglutinatis; fulcrum in cavitate in-  
vaginans; spermatophorae 12–15  $\mu$  longitudine, subramosae (modo *Cladoniae*);  
spermatia hyalina, anguste ellipsoideae, 3  $\times$  1  $\mu$ .

Thallus cerebriform, subfruticulose, lemon-yellow in younger portions to  
warbler green when the apothecia are well developed, covering areas up to 2 cm.  
in diameter, individual thalli up to 3 mm. in diameter, attached at the center,  
margins free, about 500  $\mu$  thick, upper surface smooth to deeply furrowed and  
cerebriform, under surface warm-buff, K—; cortex 20–25  $\mu$  above to 30  $\mu$  thick  
below, completely surrounding the thallus, fastigiate, of thick-walled pseudo-

parenchyma, cell lumina  $2.5\ \mu$  in diameter, densely nubilated with minute yellowish crystals, especially above, covered by an amorphous layer of gel about  $15\ \mu$  thick, with scattered granules; algal layer filling the thallus between the cortices, cells protococcoid,  $13\text{--}14\ \mu$  in diameter, often polyhedral from mutual pressure; medulla not differentiated, hyphae about  $2\ \mu$  in diameter between the algal cells.

Apothecia very numerous in the central thalli, about  $0.5\ \text{mm.}$  in diameter, circular to somewhat elliptic from mutual pressure, immersed, disc greenish black; amphitheciium not differentiated from the thallus, but often with a circular furrow about  $0.2\ \text{mm.}$  from the paratheciium; paratheciium hyaline, of periclinal hyphae about  $15\ \mu$  thick at the sides of the theciium to  $25\text{--}30\ \mu$  thick below; hypotheciium about  $15\ \mu$  thick, of grumose, densely woven, slender hyphae; theciium  $230\ \mu$  tall, the upper  $25\ \mu$  brownish and covered by a hyaline amorphous gel about  $13\ \mu$  thick; paraphyses coherent, distinct, thick-walled, about  $2\ \mu$  in diameter; asci about  $100 \times 20\ \mu$ , tips thickened when young; ascospores numerous, ellipsoid, about  $3.5 \times 1.8\ \mu$  (not seen free from ascus).

Spermogonia immersed, about  $200\ \mu$  in diameter, wall hyaline,  $15\ \mu$  thick, of thick-walled, conglutinate, periclinal hyphae; layer of spermatophores invaginated, forming cerebriform cavities, spermatophores  $12\text{--}15\ \mu$  long, somewhat branched (*Cladonia* type); spermatia hyaline, narrow ellipsoid, about  $3 \times 1\ \mu$ .

On weathered reddish granite, A. M. Gwynn *Li21*, *Li27*.

LECANORA GRISEOMARGINATA Dodge & Baker, Ann. Mo. Bot. Gard. 25:572. 1938.

Growing on moss cushion, A. M. Gwynn *Li20*. New to MacRobertson Land.

LECANORA EXSULANS (Th. Fr.) Dodge & Baker, Ann. Mo. Bot. Gard. 25:570. 1938.

*Lecanora chrysouleuca* v. *melanophthalma* f. *exsulans* Th. Fr., Nyt Mag. Naturvidensk. 40:208. 1902.

A. M. Gwynn *Li21*, *Li24*, *Li38*, *Li31* (a single young plant not sectioned).

PARMELIA JOHNSTONI Dodge, B.A.N.Z.A.R.E. Rept. B. 7:191. 1948.

Growing over weathered rocks and mosses, A. M. Gwynn *Li21*, *Li22*, *Li23*, *Li25*, *Li28*, *Li31*.

ALECTORIA CONGESTA (Zahlbr.) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:195. 1948.

*Parmelia pubescens* v. *congesta* Zahlbr., Deutsche Südpolar Exp. 8:52. 1906.

On rock, A. M. Gwynn *Li29*.

PROTOPLASTENIA CITRINA Dodge, B.A.N.Z.A.R.E. Rept. B. 7:222. 1948.

The color is more orange than in the type and all the material is sterile, although the thallus agrees microscopically.

Growing over moss cushions, A. M. Gwynn *Li20*, *Li21*, *Li25*.

GASPARRINIA HARRISSONI Dodge, B.A.N.Z.A.R.E. Rept. B. 7:235. 1948.

Thallus about 5 cm. long and 2 cm. wide, apparently starting near the edge of the rock fragment, so probably capable of forming a circular thallus about 5 cm. in diameter when the substrate permits. *A. M. Gwynn* Li26, Li31, a smaller thallus.

XANTHORIA MAWSONI Dodge, B.A.N.Z.A.R.E. Rept. B. 7:236. 1948.

*A. M. Gwynn* Li20, Li28, Li32.

BUELLIA JOHNSTONI Dodge, B.A.N.Z.A.R.E. Rept. B. 7:249. 1948.

*A. M. Gwynn* Li28, associated with *Lecanora exsulans* (Th. Fr.) Dodge & Baker, as in the type. New to MacRobertson Land.

RINODINA FRIGIDA (Darb.) Dodge, B.A.N.Z.A.R.E. Rept. B. 7:259. 1948.

*Buellia frigida* Darb., Brit. Nat. Antarct. "Discovery" Exp., Nat. Hist. 5:Lich.:7. 1910.

*A. M. Gwynn* Li21, with lecanorine apothecia nearly immersed; Li27, Li33, larger older thallus up to 6 cm. in diameter.

NOSTOC sp.

Several thalli growing on a moss cushion, akinetes abundant. A few young perithecia or cleistothecia were seen which may be parasites, or perhaps the thalli are those of a Pyrenidiaceous lichen. Very few fungus hyphae were seen in the gel between the algal filaments but in one or two places there is a faint suggestion of a cortex. Some thalli contained a few bacterial colonies. We hope it will be found again in a more mature condition, if it be a lichen.

*A. M. Gwynn* Li20, along with *Lecanora griseomarginata* Dodge & Baker and sterile *Protoblastenia citrina* Dodge.

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## EXPLANATION OF PLATE

## PLATE 15

- Fig. 1. *Ephelidium beardensis* Dodge & Rudolph.  
A. Cross-section of thallus.  
B. Cross-section of orthidium.  
C. Conidiophores.  
D. Conidiospores.
- Fig. 2. *Acrospora Gwynni* Dodge & Rudolph.  
A. Cross-section of apothecium.  
B. Cross-section of thallus showing spermogonium.  
C. Ascus.  
D. Spermatophores.
- Fig. 3. *Collemopsidium pyrenuloides* Dodge & Rudolph.  
A. Ascospores.  
B. Algal colonies.

DODGE &amp; RUDOLPH—LICHENOLOGICAL NOTES, I-IV



1



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DODGE & RUDOLPH—LICHENOLOGICAL NOTES, I-IV

PLATE 16

Fig. 1. Heard Island, Laurens Peninsula.

Fig. 2. Heard Island, Coast of Atlas Cove.

*(Photographs taken by the Australian National Antarctic Expedition.)*

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### THREE NEW ANNONACEAE FROM PANAMA<sup>1</sup>

ROBERT E. FRIES

**ANAXAGOREA Allenii** R. E. Fr. n. sp.—Arbor circ. 6 m. alta; ramuli novelli brevissime rufo-tomentelli. Foliorum petiolus 10–12 mm. longus, crassus; lamina papyracea, (exsiccata) flavo-viridis, supra glaberrima laevisque, subtus demum glaber et pallidior, oblongo-lanceolata, basi rotundata, apicem versus sensim longaeque angustata, 30–35 cm. longa et 8–10 cm. lata; costa supra subplana, subtus valde prominens, teres, rugosus; nervi laterales I. utrinque circ. 15, sub angulo circ. 80° exeuntes, deinde sursum curvati, sicut venulae subtus paulo elevatae. Pedicelli florum breves (3–5 mm. longi), crassi, sicut sepala et petala rufo-tomentelli, juxta calycem bractea vaginaeformi instructi. Sepala ovato-orbicularia, apice rotundata, non recurvata, 7–10 mm. longa. Petala crassa, exteriora oblonga, apicem rotundatum versus haud angustata intus apicem versus carinata, ad 12 mm. longa et 5 mm. lata; petala interiora lanceolata, acutissima, ad mediam partem pilosa et supra medium intus carinata. Stamina linearia, 3 mm. longa; appendix connectivi tenuis, circ. 0, 7 mm. longa, apice rotundato-truncata. (Fructus ignotus).

CANAL ZONE: Quebrada López, alt. 30 m., in flower, Feb. 11, 1940, P. H. Allen 2143 (Type in Herb. Missouri Bot. Garden).

This species is very like the *Anaxagorea crassipetala* Hemsl., found in Guatemala and Nicaragua, but differs from this especially in its leaves being larger, rounded at the base, and with much-elongated, almost thread-like apices; in its pedicels being short and thick, in its sepals being longer and of rounded oval, not triangular-shape, and its outer petals longer and not tapering toward their apices. It is also similar to *Anaxagorea dolichocarpa* Sprague and Sandwith, from which it differs by sepals rounded at the tips and not retroflexed, short inner petals, shorter stamina, etc.

**UNONOPSIS panamensis** R. E. Fr. n. sp.—Ramuli novelli pilis brevibus ferrugineis erecto-adpressis vestiti. Foliorum petiolus teres vel supra planus, tomentellus, 4–5 mm. longus; lamina chartacea, exsiccata flavo-virens, supra laevis et primo in costa minute hirsuta, demum omnino glabra, subtus in costa hirsuta glabrescens, oblongo-oblancoolata, supra medium latissima, basi breviter acuta, apice abrupte contracta et 1–1.5 cm. longe cuspidata, 15–20 cm. longa et 4–5 cm. lata; costa utrinque elevata; nervi validiores utrinque circ. 15, arcuatim adscendentes et 1–2 mm. a margine conjuncti, tenues et supra elevati; reticulum venularum in foliis adultis haud conspicuum. Inflorescentiae ex axillis foliorum delapsorum evolutae; pedicelli florum crassi, ferrugineo-sericei, breves (7 mm. longi vel ultra?), paulo supra basin articulati. Sepala inter se libera, rotundato-ovata, acutiuscula, circ. 2 mm. longa. Petala rigida, exsiccata nigrescentia, exteriora rotundata et extra ferrugineo-sericea, circ. 7 mm. in diam., interiora minora, secundum nervum medium ferrugineo-tomentosa. Stamina 1.8–2 mm. longa,

<sup>1</sup> Issued June 23, 1955.

apice truncata. Ovaria 1, 5 mm. longa, prismatica et breviter strigosa, stigmatibus globoso-ovoideo coronata; ovula 3-4, lateralia. (Fructus ignotus).

PANAMÁ: Cerro Campana, trail from Campana to Chica, alt. 600-800 m., with flowers Aug. 10, 1941, *Allen 2647* (Type in Herb. Missouri Bot. Garden).

The material is unfortunately scanty, with no fruits at all. The number and lateral positions of the ovules, however, prove it to be well differentiated from the Central American species *U. Pittieri* Saff. and *Schippii* R.E.Fr. Flowers of the third and last Central American species, *costaricensis* R.E.Fr. (*Acta Horti Bergiani* 13:105. 1941) are unknown so far, but its fruit structure with one single oblique to horizontal seed favours the view that, structurally, the flower agrees with that of *Pittieri-Schippii*, and accordingly differs from *panamensis*. *Unonopsis panamensis* also differs from *costaricensis* in having much larger and differently shaped leaves. In my survey of the species of this genus (*Acta Horti Bergiani* 12:237) *panamensis* should be ranged among the *guatteriodes*, *obovata*, and allied species, but cannot be joined to any of these.

*GUATTERIA INUNCTA* var. *caudata* R. E. Fr. nov. var.—Differt a typo foliis pro rata angustioribus, basi longe cuneato-angustatis, apice acumine 2-3.5 cm. longo caudiformi acutissimo ornatis, pedicellis florum tenuioribus.

BOCAS DEL TORO, vicinity of Chiriquí Lagoon, Old Bank Island, *von Wedel 2108* (Type in Herb. Missouri Bot. Garden).

## THE BOTANICAL CATALOGUES OF AUGUSTE DE ST. HILAIRE

JOHN D. DWYER\*

The recent essay of Jenkins<sup>1</sup> serving as an introduction to Auguste de St. Hilaire's *Esquisse de mes voyages au Brésil et Paraguay* focused considerable attention on this French naturalist who collected plants and animals in southeastern Brazil during 1816–1822. Few of the 30,000 plant specimens collected by St. Hilaire<sup>2</sup> have found their way into other botanical institutions from the herbaria of the Muséum National d'Histoire Naturelle in Paris or the Université de Montpellier<sup>3</sup>. This has contributed to the failure of many modern monographers of Brazilian plants to cite St. Hilaire material.

While studying at the Muséum National d'Histoire Naturelle in Paris I came upon the ten handwritten books constituting the catalogues of plants collected by St. Hilaire<sup>4</sup>. It is my hope to demonstrate the importance of these catalogues and also to rectify some errors made in the handling of the St. Hilaire collections.

I wish to express my thanks to Prof. H. Humbert, Directeur Laboratoire de Phanérogamie, Muséum National d'Histoire Naturelle, Paris, France, for permission to examine and to have microfilmed the catalogues of Auguste de St. Hilaire, as well as to use the facilities of the Herbarium. I owe especial gratitude to Monsieur J. Leandri, Sous-Directeur of the same institution, for his substantial assistance. To Mr. George Swett, Examiner of Questioned Documents, Clayton, Mo., I extend my heartfelt appreciation for his comparison of handwritings found in and related to the catalogues.

### ST. HILAIRE IN BRAZIL

St. Hilaire set foot on Brazilian soil at Rio de Janeiro on June 1, 1816. He was destined to be the first French naturalist to penetrate into the interior of southeastern Brazil. Rio de Janeiro, the infant capital of Portuguese Brazil, was from the time of Vellozo in 1780 the hub of botanical activity in South America. Three years before the arrival of St. Hilaire, Georg von Langsdorff, a German, found the capital an ideal center for his botanical work. Two English collectors who botanized in Rio de Janeiro and in São Paulo, Brazil, James Bowie and Alan

<sup>1</sup>Jenkins, A. E., in *Chron. Bot.* 101:5–21. 1946.

<sup>2</sup>*Rapport sur le voyage de M. Auguste de Saint-Hilaire dans le Brésil et les Missions du Paraguay*, lu à l'Académie Royale des Sciences, de Jussieu Rapporteur. 8 pp. Paris, 1823. This rare reprint may be found in the library of the Missouri Botanical Garden, St. Louis, Missouri, as well as the Oliveira Lima Library, Catholic University, Washington, D. C.

<sup>3</sup>In America, for example, there are less than 100 sheets of St. Hilaire material deposited in the Smithsonian Institution (U. S. National Herbarium), Washington, D. C., and less than 40 sheets in the Missouri Botanical Garden, St. Louis, Mo.

<sup>4</sup>I wish to express my gratitude to the National Science Foundation, Washington, D. C., for the grant of money to defray in part the expenses of travelling to the VIIIth Botanical Congress held in Paris in the summer of 1954; at the Muséum d'Histoire Naturelle I had the opportunity to examine the catalogues first hand. I prefer to speak of the books as *catalogues*, despite the fact that it may be more accurate to designate the ten books collectively as a *catalogue*.

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Cunningham<sup>5</sup>, in their unpublished (Brazilian) diary speak of visiting "Mr. Langsdorff's garden" on January 10, 1815. Four fellow-countrymen of Langsdorff had already penetrated into the interior of southeastern Brazil: Sellow, von Chamisso, Eschscholtz, and Maximilian, Prinz zu Wied-Neuwied. The most illustrious German systematist of this era, von Martius, was soon to arrive (July, 1817). Urban's account of St. Hilaire's five "voyages" informs us that St. Hilaire met two of these botanists, Langsdorff and Sellow<sup>6</sup>.

One of the most concise and accurate summaries of the travels and activities of St. Hilaire during his five journeys into the interior from Rio de Janeiro in search of plants, animals, minerals, etc. is to be found in the report of St. Hilaire's travels presented to the French Academy by Baron Cuvier and five other members. This represents the acceptance by the Academy of St. Hilaire's *Aperçu d'un voyage dans l'intérieur du Brésil* of the previous year<sup>7</sup>. I have taken the liberty of translating a section of this "summary" from the French. Wherever possible, the spelling of geographical names has been changed to that of modern usage.

After speaking of St. Hilaire's arrival in Brazil we read:

In the following December he proceeded northwards, in the province of Minas [Gerais], a territory as vast as France, where he sojourned for 15 months in order to explore its various parts. At first he headed in the direction of Villa Rica, penetrating into old and very extensive forests, covering in turn open country with a different flora, with different birds and insects. There he discovered a "quinquina" unlike the Peruvian kind, but used in the same way, and serving as an indicator of iron. Likewise he observed a grass sticky to the touch, growing luxuriantly in habitats formerly covered with virgin forests. After an illness of a month's duration in Villa do Principe, he travelled through other forests, situated to the east of this town and studied the survivors of several ancient Indian tribes. He noted in the "district" of Minas Novas a change in the flora, with woods composed of only small shrubs. Further on, other trees of greater stature appeared, called *Catingas*, which are leafless during the dry season. He spent fifteen days on the banks of the Jequitinhonha in the midst of the Botocudos, warlike Indians who live in the forests, naked and without definite dwelling places. From there he turned toward the mighty San-Francisco river, followed along its banks and entered the District of the Diamonds [Diamantina] and visited the areas where he had previously noted their methods of extracting gold from the mountains and rivers. Returning to Villa Rica by a long detour, he again headed for Rio (de) Janeiro arriving in March of 1818, whence he sent to the Muséum d'Histoire Naturelle a shipment of 200 birds, some quadrupeds, 800 species of insects, and two hundred packets of seeds, as well as two botanical papers which have been printed in the publication of the Muséum.

A second voyage of several months duration brought him to the maritime districts, to the north of Rio de Janeiro, as far as the Rio Doce, and yielded just about the same materials as those collected in the woods adjacent to the capital with the exception of those markedly different ones found on the sandy expanses. He visited Cabo Frio, the town of San Salvador de Campos, the entire province of Espírito Santo, the unhealthy banks of the Rio Doce, and having embarked at Villa da Victoria, he returned by sea to Rio de Janeiro, whence he sent a new shipment of animals and of seeds to the Muséum.

His third voyage, the longest and most important, begun in January of 1819, was at first toward the northwest in the eastern section of the province of Minas [Gerais] where he saw a beautiful waterfall at the source of the São Francisco, and the sulphur springs of Araxá whose waters cattle drink unhesitatingly. To arrive at Goiaz he followed a barren plateau

<sup>5</sup>Bowie and Cunningham were to depart from Rio de Janeiro in October of 1816, the former to collect at the Cape of Good Hope, the latter in Australia. Their unpublished Brazilian journal is at the Royal Botanic Gardens, Kew, England.

<sup>6</sup>Urban, L., in Martius' *Flora Brasiliensis* 11:93-98. 1906.

<sup>7</sup>St. Hilaire, Auguste de, in *Mém. Mus. d'Hist. Nat.* 9:307-380. 1822.

whose opposite sides form the sources of the São Francisco river and the Dos Tocantins both entering the sea from different directions. The vegetation struck him as being little different from that seen on the banks of the São Francisco. The pastures were at times entirely barren, at times covered with small stunted trees. M. de St-Hilaire after having visited Villa Boa, capital of the province of Goiás, spent a few days among the Coyapos Indians, then went to the border of Matto Grosso; from here he took a southeastern route to São-Paul. He arrived there in December 1819, after a long and arduous journey marked by great heat and dryness, and here he deposited his various collections, packed with care, to permit him to continue southwards.

At first he skirted the western side of the vast chain of mountains which separate the interior of the country from the seashore, and saw in succession the following villages: Sorocaba, Itu, Pôrto Feliz and their environs; he noted the boundaries of the most important colonial industries. Then he entered Campos Gerais, such delightful country because of its diversified countryside. He made a goodly collection of plants which indicated a more temperate climate. There he observed the erroneously named *herbe du Paraguay*; this he correctly identified as a tree of the genus *Ilex*. He also identified the local *quinquina* which is in reality a *Solanum*. Crossing over a chain of mountains at a difficult spot called Serra de Paranagoa, he found himself at the sea coast at a much lower altitude and hotter than the interior plateau whose crops approximate more those of the tropics even as far south as 27° latitude. He was able to visit the islands of St. Francis and of St. Catherine and their whaling-posts. Here the ground beyond is a sandy and dry stretch enlivened only by the presence of a prodigious number of aquatic birds.

The province of Rio Grande, which he soon entered, is very fertile, with a more vigorous population. He observed that the culture of sugar-cane stops at about 30° while cotton-growing extends to 31°, palms to 34°, just as noted in New-Holland [Australia]. He spent the winter, already severe in these areas, at Pôrto Alegre and at Rio Grande, departing in October 1820, that is in the springtime of this country. The plants which flourish at this time belong to the same genera as those constituting the spring flora in Europe, such as the *carex* [sedges], *anemones*, *centunculus* [chaffweeds], *arenaria*, etc. He recognized, too, the influence of climate on vegetation: thus, in the coldest season, the trees retained their foliage, up to a degree north of Pôrto Alegre; a third lose their leaves at Rio Grande, and at two degrees further south scarcely a tenth have retained their leaves.

M. de St. Hilaire then entered the Spanish possessions, passed through several towns and beautiful estates along the banks of the Rio de la Plata, arriving at Montevideo where the vegetation appeared to him to be so closely related to that of Europe that he scarcely found fifteen plants which could not have been assigned to European families. He also noted around certain towns that several of our own plants were well acclimated; he called attention to this especially near Montevideo, where vast waste-lands were covered with our *cardon* [thistle] growing wild and used solely as fuel. Proceeding then in the direction of the Rio Negro, a river rushing headlong into Uruguay, he found beyond a country considerably less populated and with customs agreeing with the descriptions of Azzara. His journey became more difficult between Belem and the province of the Missions, and he spent thirteen days in an uninhabited desert, populated only by *autruches* [rheas], *cerfs* [deer], and *jaguars*, against which he had to defend his own life, and especially that of his horses; unfortunately he could not save all of the horses. It was in this district that curious accidents befell him and his two companions after having eaten several spoonfuls of a honey made by a species of wasp. He visited the seven small villages which are all that remain of thirty which constituted in time past the ancient missions of Paraguay. Observing these carefully, he could naught but groan at finding only ruins and the sight of such misery in a fertile land whose former splendor our writers have not exaggerated. Then re-entering Brazil proper and traveling in the rainy season, he frequently ran the risk of losing his notes and collections; he returned at the end of a year by a detour to Pôrto Alegre, embarked on Lake Patos for Rio Grande; returned by sea to Rio Janeiro, where he arrived toward the end of 1821, after an absence of nearly three years.

St. Hilaire has elaborated on his travels in his own *Esquisse* (loc. cit.) and his *Voyages*. These are in need of careful study by contemporary scholars.

The recent remarks of the Brazilian P. R. Reitz (Anais Botânicos do Herb. Barbosa Rodrigues 1:86. 1949) on St. Hilaire reflect the warm affection of the Brazilians for the French naturalist. I have taken the liberty of translating freely the same from the Portuguese:

He had a kind heart, adapting himself to the environment in which he lived and likewise to the uneducated people with whom he often traveled, treating with the manners of a gentleman those who helped him, censuring amiably those who treated him badly.

He described objectively the customs of our lands. St. Hilaire stands in marked contrast to those pseudo-investigators who, as tourists, describe our country as a grand carnival from the seats of gambling halls or even from the summit of Corcovado<sup>8</sup> where they sit to write their observations, their memoirs of the people, of the Brazilian way of life and customs. Only a St. Hilaire, a Martius or a Bonpland who came to Brazil with great sacrifice, who traveled through inhospitable areas, could sense the pulse of the Brazilian heart not only in the cities but in the back country and small villages, could see in their habitats great diversity of plants, animals, and minerals. Only these or others of their calibre could describe, in the role of investigators, our natural riches and our people.

There is an excellent map of the itinerary of St. Hilaire's five "voyages", prepared by J. Santos for *Chronica Botanica* (loc. cit. p. 12), from St. Hilaire's original in the back of his *Voyage à Rio Grande do Sul*. A large map found in the first volume of *Martius' Flora Brasiliensis* labelled "Itinera Botanicum" with inked-in itineraries of the majority of the principal botanists who collected in Brazil from 1780 to 1852 is unfortunately inaccurate, at least with respect to St. Hilaire. For example, the delineator indicates that St. Hilaire collected as far north on the eastern coast of Brazil as Villa de Porto Seguro (Bahia); this is almost 225 miles north of the Rio Doce, the most northeastern limits of St. Hilaire's collections.

#### THE CATALOGUES OF ST. HILAIRE

The catalogues are made up of separate books in St. Hilaire's own handwriting. Approximately 8900 collections are entered in the 1575 pages<sup>9</sup>. My count from the catalogues stands in marked contrast to Urban's statement (*Martius' Flora Brasiliensis* 1<sup>1</sup>:92-98, 1906) of the number deposited in three herbaria, that: "Collectio princeps (cr. 7600 numeri) in herbario musei historiae naturalis Parisiensis. Dupla in Montpellier, parca in museo Berolinensi". Urban's estimate may have been the result of adding up the collection numbers in the catalogues without considering that often single collection numbers were subdivided one to several times, or from St. Hilaire's own statement (*Esquisse*, p. 61) that: "Le nombre des plantes que j'ai recueillies s'élève à environ sept mille . . .". In the catalogues there are approximately 835 collection numbers which are subdivided *a la "bis"*, *"ter"*, *"4"*, etc. In one instance (in series C<sub>2</sub>) the collection number 2791 is subdivided thirteen times and applied to eleven different families of angiosperms. The failure on the part of monographers or copyists to add "bis", "ter", etc. to a specific collection number has caused considerable confusion in the citing of specimens.

Following each collection number is (usually) the specific plant family (written in French) to which the collection belongs. Occasionally only the generic name is given. For approximately 550 collection numbers St. Hilaire fails to supply any taxa although usually one finds an "analysis" or a few words. In more than one

<sup>8</sup>A high peak overlooking Rio de Janeiro easily reached in our times by street-car.

<sup>9</sup>In a letter recently received, M. Leandri writes: "Our catalogue of entries bears actually 7692 gatherings [collections] from St. Hilaire; maybe the others have been lost or kept by A. de Jussieu and Cambessedes (and others)."

third of the entries a detailed description ("analysis") of the plant is given in French. In some families, for example in the Orchidaceae, these descriptions may take up three full pages. St. Hilaire paid particular attention to listing the common names of the plants as well as their economic uses. The place of collection is usually found at the end of the "analysis".<sup>10</sup> The "analyses" are models of precision and critical observation. St. Hilaire himself states (*Esquisse*, p. 61) ". . . je les ai toutes analysées sur les lieux-mêmes, et me suis principalement attaché à la dissection des parties dont la connaissance répand le plus de lumières sur les rapports naturels".

Dreuzy, a great-nephew of St. Hilaire, in an appendix to the *Voyage à Rio Grande do Sul*, refers to the difficulties encountered by Saint Hilaire in preparing his "journal botanique", the name by which Dreuzy apparently designates St. Hilaire's diary and his catalogues collectively:

Nous donnons ci-dessous quelques extraits de ce volumineux journal pour faire comprendre au lecteur quel travail s'imposait l'auteur au soir de chacune de ses fatigantes journées de voyage, assis sur ses malles sous un rancho, éclairé par la lueur tremblante d'une chandelle fumeuse, dévoré par les moustiques qu'attirait la lumière.

Dreuzy then supplies two samples of St. Hilaire's "analyses" from catalogues C<sup>2</sup>, Section 2, one collection number 2682, and the other 2787<sup>11</sup>. To my knowledge these are the only "analyses" which have been published *in toto*. In fact, I have found no reference of any length in the literature concerning St. Hilaire's catalogues. We may use Dreuzy's sample 2682 as typical of an "analysis" of St. Hilaire:<sup>11</sup>

ESTANCIA DE SANTO-REI, 1<sup>er</sup> mars, n° 2682. Graminée. Sur chaque dent de l'épi sont 2 fleurs, l'une sessile, l'autre pédiculée. Épillets sessiles, 1 fl. herm., lancéolés, sous-falciformes, glumes 2-valves, à valves ext. hérissée, lancéolée, tantôt simplement aiguë, tantôt courtement 1 ou 2 arrêtées à valv. int. un peu plus courte que l'autre lancéolée-aiguë, pubescente. Glumelles 2-valv., à valv. membraneuses sous-violettes, sous-pubescentes presque égales, obtusiuscules, 2 paléoles tronquées; 3 et 2 styles sétacés, 2 stig., complets, continus, plumeux, ovaire glabre ovoidé. Épillets pédicelles mâles. Glumes 2 valv. à valve ext. pubescente, lancéolée-linéaire-aiguë, plane, à valve int. lancéolée-aiguë, presque égale à l'autre pubescente carénée, 2 paléoles tronquées. 2 ét. glumelles 2 valv. à valves lancéolées, linéaires, aiguës, presque égales, ciliées, membraneuses, un peu violettes. Toute la plante répand une forte odeur de citron. Nom. vulg. *capim limao*.

Unfortunately, St. Hilaire made no great effort to list binomials in the catalogues. In the more than 8900 collection numbers there are approximately 160 binomials, the majority in St. Hilaire's handwriting and a few in Spach's. Most of

<sup>10</sup>The catalogues do not list as many specific localities as does Urban in his elaborate list of the itineraries of St. Hilaire in *Martius' Flora Brasiliensis* (loc. cit.). Here more than 800 localities are given arranged in proper sequence as well as according to the years of St. Hilaire's five "voyages". It is probable that Urban gleaned this detailed itinerary from St. Hilaire's own published reports of his trips.

<sup>11</sup>Unfortunately, in 2682 Dreuzy terminates this "analysis" of a Graminée with the binomial *Echites guaranitica* Aug. de S.-H. This binomial, despite the fact that it appears in the catalogues to be written into this "analysis" at the upper right-hand corner, obviously refers to collection number above, 2681 (Apocynacée). To make matters worse, the second "sample" analysis is labelled "*Composée* 2787<sup>11a</sup>." From the catalogues the collection number is simply 2787.

the binomials are addenda to the "analyses"; those written by St. Hilaire belong as a rule to families on which he published extensively: e. g., Violaceae (including certain genera now assigned to the Ochnaceae), Droseraceae, etc. For some reason "analyses" of certain families, e. g., Malvaceae, Malpighiaceae, etc. are often cross-hatched in ink. In the case of the Rutaceae the numbers of the family were designated by a scrawled name which looks like "Oranger" (pl. 17, under 2791<sup>12</sup>).

Figures 1 and 2 show the number of collections made in specific families (with the exception of the ferns) according to the catalogues of St. Hilaire. Figure 1 lists the families represented by more than 50 collection numbers; fig. 2 lists those represented by less than 50 and more than 20 collection numbers. The family Leguminosae is considered *in sensu lato* to include the Mimosaceae and Caesalpinaceae. The Ochnaceae includes certain genera which St. Hilaire related to the Violaceae, e. g., *Sauvagesia*, *Lavradia*. To avoid confusion I have combined the Liliaceae with the Amaryllidaceae.

#### NUMERICAL SEQUENCES OF ST. HILAIRE COLLECTIONS

In preparing a collection of plants for herbarium deposit the most convenient sequence of collection numbers is a continuous linear one which is correlated with the date of collection and the itinerary of the collector. In examining the more than 8900 collections of St. Hilaire we find the following numerical sequences<sup>12</sup> in the ten books:

Book 1—	1- 758	Book 6—	86- 96
Book 2—	{ 464- 650	Book 7—	{ 1- 60 (not in St. Hilaire's handwriting)
	1B- 132B		1-1175
Book 3—	1- 63, 103-2085	Book 8—	{ 1176-1899, 2000-2797
Book 4—	1- 112		1- 219
Book 5—	{ 2101-2489	Book 9—	692- 709, 1858-1869, 2004-2120
	1- 408	Book 10—	1- 818

Despite the patch-work pattern of these sequences of numbers definite correlations exist between sets of numbers and the itineraries of St. Hilaire's five voyages. It is not impossible that St. Hilaire prepared the catalogues *following* his return to Paris in 1822. I have seen certain individual "analyses" attached to herbarium sheets in the Paris Herbarium, e. g. to one of several of St. Hilaire's unnumbered collections of *Lavradia capillaris* (Ochnaceae). It may be that the "analyses" were written on separate sheets of paper in the field, inserted separately with the unmounted specimens and then removed in Paris to be gathered together and recopied into a catalogue. The mounting of his 30,000 specimens in Paris may have resulted in some confusion in the re-organization of the "analyses" in the catalogues. Occasionally, one finds the date 1822 at the end of an analysis, suggesting that an addendum was made to the original more-abbreviated "analysis". The "analyses", too, are generally written in a neat (but often difficult to decipher)

<sup>12</sup>In a given run of a number in the catalogues it is not uncommon to find occasional numbers missing or out of place. For the sake of brevity I am not specifying these, although the absences have been taken into account in computing the sum-total of collection in the catalogues.

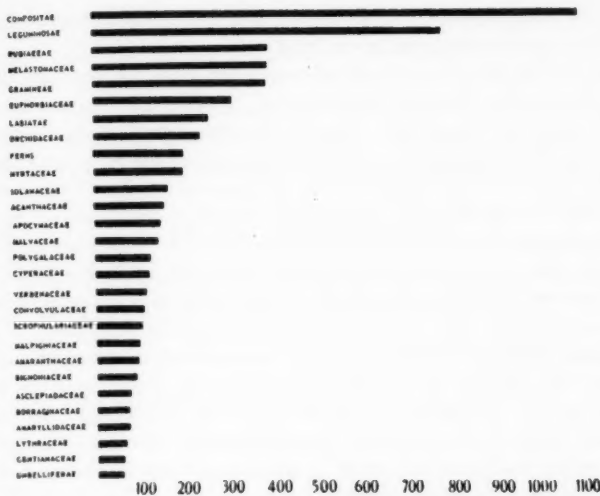


Fig. 1. Approximate numbers of collections listed under specific families of Angiospermae (except for Ferns) in the botanical catalogues of Aug. de St. Hilaire. Only those families with collections in excess of 50 are shown.

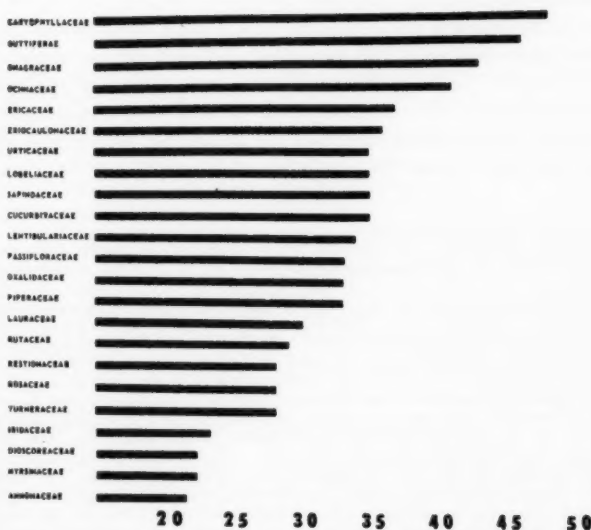


Fig. 2. Approximate numbers of collections listed under specific families of Angiospermae in the botanical catalogues of Aug. de St. Hilaire. Only those families with at least 20 and not more than 49 collections are shown.

hand. Perhaps legibility is too much to expect of a scientist working in the evening after an exhaustive day in the field.

In Book 5 Weddell writes that certain notes for collection numbers 2085-2101 were not sent to the Museum for insertion. Several points argue against this possibility, however. In the first place, it is more logical, if not more safe, to insert the "analyses" initially into a field book; again we note, especially in the early books, that St. Hilaire often fails to complete an "analysis" before beginning the next collection number but occasionally completes the "analysis" on another page and consequent to a different collection number. It is difficult to believe that he would do this if he were preparing the catalogues in Paris. The fact that volume 6 has only 11 collection numbers sandwiched in with what is obviously a segment of his diary written in the field is another substantial point of evidence.

St. Hilaire and his contemporaries used these numbers in the catalogues of collections and for herbarium sheets, and not for purposes of citation in the literature. St. Hilaire and his co-workers in the *Flora Brasiliae Meridionalis*, Jacques Cambessèdes and Adrien de Jussieu, never cite collections by number. No doubt, they did not consider individual collections to be as important as do our botanists of today who adhere to the principles of the type concept.

Obviously, if a collection of St. Hilaire had been cited, e.g., No. 26, the reader would wonder to which sequence to assign it unless the locality were given. Weddell<sup>13</sup>, no doubt stimulated by the pioneer efforts of certain authors in *Martius' Flora Brasiliensis* in citing collectors and collection numbers, attempted (probably in the 1860's) to organize the catalogues in a manner more suitable for citation and for labelling of specimens. Unfortunately, Weddell did not publish his "Key" to the catalogues<sup>14</sup>. The facts that Spach, who was curator of the herbarium at the Muséum d'Histoire Naturelle, employed Weddell's system on printed labels and that certain monographers have used the Weddellian system give some status to the key. We shall discuss the popularity of Weddell's key in following paragraphs.

<sup>13</sup>H. A. Weddell (1819-1877), an "aide-naturaliste" to Adrien de Jussieu, collected extensively in Brazil; in addition he was a distinguished taxonomist at the herbarium of the Muséum d'Histoire Naturelle, Paris.

<sup>14</sup>In recent years some members of the staff of the Muséum d'Histoire Naturelle, Paris, prepared a typewritten copy of Weddell's key. Weddell's handwritten key may be found scattered in the front of the catalogues of St. Hilaire (see pl. 18). An accurate handwritten summary (not figured here) of the sequences of numbers (accompanied by broad geographical data) of St. Hilaire's botanical collections occurs in the initial two pages of Book 8 of the catalogues. Mr. Swett, Examiner of Questioned Documents, Clayton, Missouri, expresses the probability that this was prepared by a person (or persons) other than St. Hilaire, Weddell, or the author or authors of the page shown in pl. 19. It was obviously not prepared by Spach. I have elected to credit Weddell with the establishment of the key to St. Hilaire's collections. That Weddell inserted notes in numerical sequences and geography in many of the books of St. Hilaire seems certain. M. Leandri of the Laboratoire de Phanerogamie, Muséum d'Histoire Naturelle, Paris, writes me that the typewritten key was "copied from notes in the books [St. Hilaire's catalogues] partly of the handwriting of Weddell". While Weddell may have based his insertions on the well-organized summary found in book 8, it seems safer to suppose that the latter was prepared from his notes.

## WEDDELL'S KEY TO THE CATALOGUES OF ST. HILAIRE

Weddell divided the books<sup>15</sup> constituting St. Hilaire's catalogues into four series: A (books 1, 2, 3, and 4); B (books 5 and 6); C (books 7, 8, and 9); and D (book 10). Series A is divided into two volumes, B, into two volumes, C, into three volumes, and D consists of one volume. The following revised outline is based on a recent typewritten summary of Weddell's key found in the herbarium at Paris:

## SERIES A (TWO VOLUMES)

A<sup>1</sup>, comprising numbers 1-758.—

Plants collected during the year 1816, some in the vicinity of Rio de Janeiro (1-469 and 651-758), others in the vicinity of Uba, on the Rio Paranyha about 25 leagues from Rio de Janeiro, and in the same province (470-650).

A<sup>2</sup>, in two sections.—

Section 1, comprising numbers 464-650, which are duplications of the same numbers in Volume A<sup>1</sup>.

Section 2, comprising numbers 1B-130B (or 132B). Plants from the environs of Rio de Janeiro collected in 1818.

## SERIES B (TWO VOLUMES)

B<sup>1</sup>, comprising numbers 1-2085 (December 1816 to March 1818).—

Plants collected in the province of Minas Gerais, with the exception of 1-25, which are from the province of Rio de Janeiro.

B<sup>2</sup>, in two sections.—

Section 1, comprising the numbers 2101<sup>b1a</sup> to 2493; these follow in order the series of plants of Minas Gerais which constitutes the three previous volumes.

Section 2, comprising the numbers 1-408. Plants collected during a "voyage" on the seacoast of Brazil, from Rio de Janeiro to the Rio Doce in the provinces of Rio de Janeiro and Espirito Santo, from August to November, 1818.

## SERIES C (THREE VOLUMES)

C<sup>1</sup>, comprising numbers 1-1175.—

Plants collected in the following districts:

- 1- 10—Province of Rio de Janeiro. 1819.
- 11- 625—Province of Minas Gerais. 1819.
- 926- 985—Province of Minas Gerais. 1819.
- 626- 920—Province of Goiaz. Sept. 1819 to May, 1820.
- 986-1175—Province of São Paulo. Sept. 1819 to May, 1820.

C<sup>2</sup>, divided into two sections.—

Section 1, comprising numbers 1176-2797. Plants collected in the following regions:

- 1176-1704—Province of São Paulo. May, 1820.
- 1705-1806—Province of Sta. Catarina. May to June, 1820.
- 1807-1874—Province of Rio Grande do Sul. 1820.
- 2569-2797—Province of Rio Grande do Sul. 1820.
- 1875-1899 } —From San Pedro de Rio Grande to Montevideo. 1820.
- 2000-2260 }
- 2261-2568—From Montevideo to the Brazilian frontier on the banks of the Uruguay. 1820.

Section 2, comprising the numbers 1-219c.

Plants collected in the environs of Rio de Janeiro, in July, 1821.

C<sup>3</sup>.—

Comprising three small series of numbers (692-709, 1858-1870, and 2004-2020) to be intercalated in the large series of numbers contained in volumes C<sup>1</sup> and C<sup>2</sup>.

<sup>15</sup> Weddell referred to these as *volumes*.

## SERIES D (ONE VOLUME)

D, comprising the numbers 1-818.—

Plants collected in 1821 and 1822 during the last voyage of St. Hilaire, in the following places:

1- 30—Province of Rio de Janeiro.

31- 587—Province of Minas Gerais.

588- 818—Province of São Paulo.

Certain elements of confusion exist in the interpretation of these numbers. In Book 2 the numbers 464-650 are simply duplicates ("double emploi") of the same numbers in the 1-758 sequence of Book 1. The numbers 1-112 in Book 4 are duplicates of those found in Book 3 except for 64-102 which are missing in Book 3. The numbers 86-96 in Book 6 (if one should refer to this as Book 6 inasmuch as it is apparently one of St. Hilaire's diaries) belong to the sequence of numbers in Book 5 from which they have been omitted. In Book 7 the initial sequence of numbers 1-60 are not in St. Hilaire's handwriting<sup>16</sup>. In Book 8 numbers 1900-1999 are missing, apparently due to carelessness.

Weddell (?) used paper labels for all the specimens of the collections except numbers 1-758 in catalogue A<sup>1</sup> (Rio de Janeiro), 1-25 in B<sup>1</sup> (Rio de Janeiro), and 25-2085 in B<sup>1</sup> (Minas Gerais), for which parchment labels were used. All paper labels, except for numbers 2101<sup>11a</sup> to 2469 of B<sup>2</sup> section 1 (Minas Gerais), and 2470 to 2493 B<sup>2</sup> section 1 (Rio de Janeiro) bear, or should bear, symbols. This is summarized as follows:

TABLE I

Labels	Numbers	Catalogues	Localities
Paper 8	1- 240	B <sup>2</sup> Sect. 2	Rio de Janeiro
	241- 408	B <sup>2</sup> Sect. 2	Espirito Santo
Paper B	1- 130	A <sup>2</sup> Sect. 2	Rio de Janeiro
Paper C	1- 219	C <sup>2</sup> Sect. 2	Rio de Janeiro
Paper D	1- 30	D	Rio de Janeiro
	31- 587	D	Minas Gerais
	588- 818	D	São Paulo
Paper O	1- 10	C <sup>1</sup>	Rio de Janeiro
	11- 625	C <sup>1</sup>	Minas Gerais
	626- 691	C <sup>1</sup>	Goiaz
	692- 709	C <sup>2</sup>	Goiaz
	710- 920	C <sup>1</sup>	Goiaz
	926- 985	C <sup>1</sup>	Minas Gerais
	986-1175	C <sup>1</sup>	São Paulo
	1176-1704	C <sup>2</sup> Sect. 2	São Paulo
	1705-1763	C <sup>2</sup>	Sta. Catarina
	1764-1775	C <sup>2</sup>	São Paulo
	1776-1806	C <sup>2</sup>	Sta. Catarina
	1807-1857	C <sup>2</sup>	Rio Grande do Sul
	1858-1870	C <sup>2</sup>	Rio Grande do Sul
	1871-1874	C <sup>2</sup>	Rio Grande do Sul
	1875-2003	C <sup>2</sup>	Banda Oriental del Uruguay
	2004-2020	C <sup>2</sup>	Banda Oriental
	2021-2568	C <sup>2</sup>	Banda Oriental
	2569-2797	C <sup>2</sup>	Rio Grande do Sul

<sup>16</sup>These 60 numbers have neither families nor "analyses" appended, although the localities of the collections are given. Some of the localities (e. g., Barbacena, Rio Ouro Branco) suggest the beginning of St. Hilaire's second voyage to Minas Gerais in 1816. On this voyage he was accompanied by I. Gomes and G. H. de Langsdorff. Perhaps these are collections of one or both of these men.

## THE ROLE OF THE CATALOGUES OF ST. HILAIRE IN TAXONOMIC MONOGRAPHS

Although only a few botanists such as Weddell, Spach, Dreuzy, etc., are known to have consulted the catalogues of St. Hilaire, the various check-marks and binomials inserted suggest that they may have been studied by others.

Prior to an arbitrary date of 1860 monographers in citing St. Hilaire collections, in imitation of St. Hilaire, Cambessèdes, and de Jussieu failed (usually) to supply collection numbers but gave clear-cut geographical data. Later monographers often used St. Hilaire collection numbers, and, almost without exception, they furnished only a fraction of collections as listed in the catalogues. Mueller, for example, in his classic work on the Apocynaceae (Mart. Fl. Bras. 6<sup>1</sup>:1-195. 1860) gave collection numbers for only 23 of the 56 collections of St. Hilaire which he cites. These 56 collections represent about one-third of this family as listed in St. Hilaire's catalogues, all of which have specific collection numbers. In general, in *Martius' Flora Brasiliensis* it is the exception to find collection numbers when St. Hilaire material is cited; collection numbers are missing, for example, in Radlkofer's monograph of the Sapindaceae (1895), Bennett's work on the Polygalaceae (1874), Koehne's work on the Lythraceae (1887), etc. (see Table II).

No doubt much of the confusion and inconsistency encountered in the citation of St. Hilaire's collections, especially by the 19th century monographers, arise from several circumstances: (a) localization of the bulk of the St. Hilaire collections in the Paris herbarium; (b) the fact that the duplicate collections often have labels bearing only a binomial and the geographical data (often undecipherable)<sup>17</sup>; (c) the lack of interest in collection numbers by the contemporaries of St. Hilaire; (d) awkward and overlapping sequences of numbers prior to Weddell's groupings; (f) the subsequent failure to apply the Weddellian system to many of St. Hilaire's collections.

Table II, based on an examination of twenty monographs (1832 to the present) which include St. Hilaire's collections, reveals many important points<sup>18</sup>. In the Anacardiaceae (D.C. Monograph. Phanerogam. 4. 1883) Engler cites eleven collection numbers of St. Hilaire, none of which has catalogue numbers; in attempting to check them against the catalogues it appears from the blank spaces in the latter that St. Hilaire may not have been certain of the characters of the Anacardiaceae and thus never entered the family name. In Cogniaux's Cucurbitaceae (D.C. Monograph. Phanerogam. 3. 1881) the number of St. Hilaire's collections cited exceeds the total number estimated to be entered in the catalogues under this family. This disparity is a reflection of the number of blanks left by

<sup>17</sup> Of the 59 sheets of St. Hilaire reported by Dr. Lyman B. Smith, of the Smithsonian Institute (Washington, D. C.), to be in that herbarium only 34 bear collection numbers; of these only two have the Weddellian series appended to the number. I have been unable to locate ten of the numbered specimens with certainty in the catalogues.

<sup>18</sup> When the collection numbers are not listed in a monograph the author may be including more than one collection (of St. Hilaire) for the species in question without making the same clear. This makes an accurate statistical analysis of the number of collection cited impossible.

TABLE II

Specific Monograph	Date	Numb. of St. Hilaire collections cited	Numb. of St. Hilaire collections without coll. numbers	Numb. of St. Hilaire's collections with coll. numbers	Numb. of St. Hilaire collections with coll. numbs. and Weddell's series	Numb. of St. Hilaire collection numbers matching those in cat.	Numb. of collection numbers in St. Hilaire's catalogues
Malpighiaceae	1832	64	64	0	0	?	97
A. de Jussieu							
Melastomaceae	1849-1852	51	51	0	0	?	378
Naudin							
Apocynaceae	1860	58	35	23	0	16	147
Mueller							
Polygalaceae	1874	30	30	0	0	?	122
Bennett							
Erythroxylaceae	1878	8	8	0	0	?	0
Peyritsch							
Alismaceae	1881	7	0	7	6	4	6
Micheli							
Commelinaceae	1881	11	0	11	0	6	18
Clarke							
Cucurbitaceae	1881	36	0	36	35	31	35
Cogniaux							
Turneraceae	1883	15	1	14	9	10	28
Urban							
Anacardiaceae	1883	11	0	11	0	0	0
Engler							
Lythraceae	1887	24	24	0	0	?	62
Koehne							
Rubiaceae Tribes VII-XIX	1889-1889	8	7	1	0	1	386
Schumann							
Guttiferae	1893	4	0	4	1	4	46
Vesque							
Sapindaceae ( <i>Serjania</i> )	1896	19	19	0	0	?	35
Radlkofer							
Bromeliaceae	1896	19	0	19	10	7?	14
Mez							
Bignoniaceae	1897	2	1	1	0	1	91
Bureau							
Ochnaceae (Ouratées-Orthospermées)	1902	7	1	6	0	2	41
Van Tieghem							
Passifloraceae	1938	17	0	17	0	11	22
Killip							
Vochysiaceae ( <i>Salvertia</i> & <i>Vochysia</i> )	1948	8	1	7	4	4	15
Stafleu							
Labiatae ( <i>Hyptis</i> )	1949	100	8	92	2	79	244
Epling							
		497	250	249	67	176	1878

St. Hilaire after collection numbers in the catalogues, some of which are undoubtedly of the Cucurbitaceae.

In Naudin's monograph of the Melastomaceae<sup>19</sup>, we find very few of St. Hilaire's collections cited despite the fact that Naudin must have been well acquainted with them<sup>20</sup>. What is even more remarkable is the complete absence of St. Hilaire material in the "second half" of the monograph (i. e., vol. 16, after p. 87. 1851), even though such common Brazilian genera as *Clidemia*, *Miconia*, etc. are included<sup>21</sup>. In the several sample monographs from Martius' *Flora Brasiliensis* we note that few collections of St. Hilaire are cited as compared with the total number of collections of the specific families estimated to be in the catalogues.

Killip, in his recent treatment of the Passifloraceae (Field Mus. Nat. Hist. Bot. 19:1-613. 1938), cites six numbers which do not check with the corresponding ones in the catalogues. Of these, three (717, 751, and 970) were probably erroneously copied from labels bearing the numbers, 719, 753, and 976 respectively, all of which are entered in the catalogues under Passifloraceae; a fig. 9 may be easily mistaken for a 7, a 1 for a 3, etc.

Epling, in his monograph of *Hyptis* (Rev. Mus. de La Plata, n. s. Secc. Bot. 30:153-497. 1949) cites more St. Hilaire material than any contemporary monographer<sup>22</sup>. Unfortunately, only two of the hundred collections cited bear collection numbers with Weddell's series added. This suggests, of course, that the Weddellian system has not been applied in any great degree to the labelling of specimens. Despite the quantity of St. Hilaire material cited by Epling, approximately 65 collection numbers of *Hyptis* were not included in his work. In checking this genus in the Paris Herbarium 13 of the 92 collection numbers (St. Hilaire) cited by Epling, were not located; but eight of these thirteen can be located readily when "bis", "ter", etc. are appended. (Some copyist of course may have failed to insert "bis", "ter", etc. on the labels.) Of the remaining numbers, probably 578 was misread for 518, and 1155 for 1133.

In those monographs using the Weddellian system the collection numbers are usually matched with ease in the proper volume in the catalogue.

<sup>19</sup> Ann. Sci. Nat. Bot. Ser. III, 12:196-284. 1849; 13:25-39, 126-159, 273-303, 347-362. 1850; 14:53-76, 118-165. 1850; 15:43-79, 276-345. 1851; 16:83-246. 1851; 17:305-382. 1852; 18:85-154, 258-294. 1852.

<sup>20</sup> St. Hilaire and Naudin were co-authors of a paper entitled "Revue de la Flore du Brésil Meridionale" which appeared in three sections (Ann. Sci. Nat. Bot. Ser. II, 18:24-54, 209-213. 1842). In addition they were co-authors of a new genus, *Augustinea*, of the Melastomaceae (Ann. Sci. Nat. Bot. Ser. III, 2:145. 1844).

<sup>21</sup> I hope to discuss in another paper the stormy history of the Melastomaceae collected by St. Hilaire.

<sup>22</sup> *Hyptis* is one of the few cases where St. Hilaire wrote a genus name with fair consistency into his catalogues in his "analyses" instead of the family name "Labiee". However, in checking Epling's monograph against the catalogues, it is obvious that St. Hilaire did on occasion use the taxon of family in place of *Hyptis*.

## A PARTIAL LIST OF THE GENERA COLLECTED BY ST. HILAIRE

In the herbarium of the Muséum d'Histoire Naturelle, Paris, there exists an unpublished list of about 2000 entries of St. Hilaire's collection numbers; these are arranged according to genera (occasionally binomials are listed) and cover eighteen families or tribes. The author of this list is unknown<sup>23</sup>. Fortunately, the collection numbers of St. Hilaire are entered according to the Weddellian system. The presence of geographical data increases its value considerably (cf. pl. 19).

In the list the entries from numbers 1 to 364 are of the Graminée only, divided according to 13 tribes. Among the Dicotyledoneae we find the following families and tribes listed in the order given (entry numbers 1-1589):

Chloranthaceae	(entries 1-2)	Nyctagineae	(entries 150-182 <sup>bi</sup> )
Piperaceae	(entries 3-44)	Chenopodeae	(entries 183-192)
Celtideae	(entries 45-53)	Amarantaceae	(entries 193-307)
Moreae	(entries 54-85)	Aristolochiaceae	(entries 308-322 <sup>bi</sup> )
Artocarpiées	(entries 85 <sup>bi</sup> -95)	Proteaceae	(entries 323-328)
Urticacées	(entries 96-100)	Monimieae	(entries 329-337)
Salicineae	(entries 101-103)	Laurinées	(entries 338-390 <sup>bi</sup> )
Lacistemeae	(entries 103 <sup>bi</sup> -103 <sup>b</sup> )	Compositae	(entries 391-1572)
Polygonaeae	(entries 104-149)	Campanulacées	(entries 1573-1589)

It is obvious that such a list may be of great value to specialists of the above groups working on material from southeastern Brazil. As an example of its usefulness, I was able to ascertain in the model analysis (cf. p. 157) that *Elionurus* is the genus of the grass family described by St. Hilaire.

## SUMMARY

Monographers have used only sporadically the Weddellian system in checking the collection numbers of St. Hilaire's material with the specific catalogue series and section, probably due to the absence of these numbers from the majority of the labels of the specimens. The Weddellian system answers the problem of the possible overlapping of collection numbers, and monographers should be encouraged to adopt it. Being aware of the existence of the catalogues of St. Hilaire, they are now able to check collection numbers against St. Hilaire's "analyses"<sup>24</sup>. The catalogues themselves represent an original source of reference for the 8900 collections of Aug. St. Hilaire in southeastern Brazil.

The discovery of a list (author unknown) of some of the genera collected by St. Hilaire, with some 2000 collection numbers entered according to the Weddellian system, should be of great assistance to monographers.

<sup>23</sup>There are 17 collection numbers of St. Hilaire and accompanying data at the end of the list which are obviously in Spach's handwriting. This permits one to give the date of the list as some time prior to 1879, the year of Spach's death. Mr. George Swett, from a comparison of one sheet of the above list (pl. 19, a photo from microfilm) with photographs of the writings of St. Hilaire and Weddell (cf. pls. 17 and 18) expressed the opinion neither prepared the list; he qualifies this, however, by stating that "no opinion is held as to whether the writers (St. Hilaire and Weddell) executed the word *Andropogoneae* in the above sample sheet."

<sup>24</sup>The author, through the Missouri Botanical Garden, will be happy to supply sets of collection numbers of St. Hilaire for specific families to specialists.

## APPENDIX

Through a letter received during the proofing of this paper I learned that the Bibliothèque Centrale (Mus. Nat. Hist. Naturelle) has no manuscripts of Aug. de St. Hilaire except several fragments of the *Flore du Brésil Meridionale* and four of his letters. Apparently there are no St. Hilaire manuscripts in the Library of the Division de Phanérogamie of the Museum except the catalogues herein described, and a single letter.

In addition, I learned that the editor of St. Hilaire's *Voyage à Rio Grande do Sul* is Charles Roland de Dreuzy (1837-1899), a native of Nivernais. He was the grand-nephew of St. Hilaire, heir to his estate at Turpinière, and grandson of a sister of St. Hilaire. At his own expense he published the *Voyage à Rio Grande do Sul*, in accordance with the last wishes of his "parent". The chateau at Turpinière is located near Ferté Saint-Aubin, Sennely (Loiret). The present owner is M. Robert de Dreuzy, son of the editor of *Voyage à Rio Grande do Sul*.

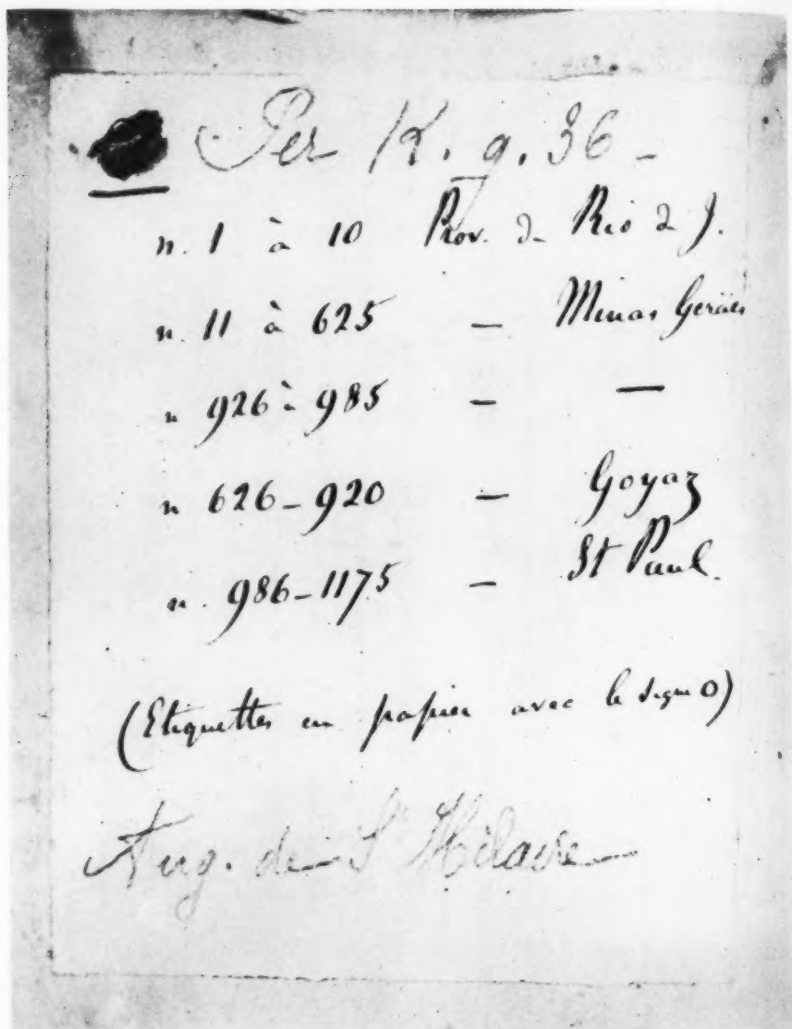
The grass described in the model "analysis" (cf. p. 157 of text) was determined by Miss Agnes Chase as *Elionurus candidus* var. *bisetosus* Hack. and Linden.

## EXPLANATION OF PLATE

## PLATE 17

A portion of one page of Catalogue C<sup>2</sup> of Auguste de St. Hilaire. This is in his handwriting and covers numbers "2791<sup>9</sup> *Hypoxis*, 2791<sup>10</sup>, Labiée, 2791<sup>11</sup>, Solanée, 2791<sup>12</sup>, Oranger", and "Suite à 2791<sup>9</sup>." The last is a continuation of the "analysis" of *Hypoxis* at the top of the page.

Dwyer—Botanical Catalogues of St. Hilair



DWYER—BOTANICAL CATALOGUES OF ST. HILAIRE

EXPLANATION OF PLATE

PLATE 18

A portion of the "key" to the botanical catalogues of Auguste de St. Hilaire. This is in Weddell's handwriting and is from Series C, catalogue C<sup>1</sup>. The handwriting at the top and bottom of the page is that of the librarian.

## EXPLANATION OF PLATE

## PLATE 19

A page from a list of approximately 2000 collection numbers of Auguste de St. Hilaire. Note that the Grasses are entered according to tribes and genera. The fourth collection entered under the genus *Elionurus* (C<sup>2</sup> No. 2682) is that upon which the "model analysis" (see p. 157) is based. Thelist is deposited in the Herbarium of the Muséum National d'Histoire Naturelle, Paris.

Pages encreintes ou l'absence	Determination et Synonymie Etat des caractères	Noms vulgaires et usages	Indications géographiques	Origins, Donateur. Noms du Catalogue d'envoi	Plumage ou marquage
m. 317	<i>Ardisia</i>		<i>Ardisia orientale</i>	ce n° 2105 h	hy.
m. 318	<i>id.</i>		<i>id.</i>	ce n° 2041 (?)	hy.
m. 319	<i>id.</i>		<i>Ardisia grande de fol.</i>	ce n° 1760 b	hy.
m. 320	<i>id.</i>		<i>Ardisia orientale</i>	ce n° 1119	hy.
<b>Tribus XII.</b>					
<i>Rottboelliaceae.</i>					
<u><i>Manisuris</i></u>					
<b>Tribus XIII.</b>					
<i>Andropogoneae.</i>					
<u><i>Eriochrysis</i></u>					
m. 331	<i>id.</i>		<i>Ardisia farnesii</i>	A' n° 184	hy. p.
m. 332	<i>id.</i>		<i>id.</i>	A' n° 186	hy.
m. 332 b	<i>id.</i>		<i>Ardisia farnesii</i>	B' n° 181	hy.
<u><i>Elionurus</i></u>					
m. 333	<i>id.</i>		<i>St Paul</i>	ce n° 1331	hy. p.
m. 334	<i>id.</i>		<i>id.</i>	ce n° 1315	hy.
m. 335	<i>id.</i>		<i>id.</i>	ce n° 1332	hy. p.
m. 336	<i>id.</i>		<i>Ardisia grande de fol.</i>	ce n° 1312	hy. p.
m. 337	<i>id.</i>		<i>Ardisia orientale</i>	ce n° 1370	hy.
m. 337 b	<i>id.</i>		<i>St Paul</i>	ce n° 1378	hy. p.
m. 337 c	<i>id.</i>		<i>id.</i>	ce n° 1381	hy.

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## COMPARISON OF JUNIPER POPULATIONS ON AN OZARK GLADE AND OLD FIELDS

MARION TRUFANT HALL\*

### INTRODUCTION

Using comparative morphology as criteria, I presented evidence in an earlier paper (Hall, 1952) that *Juniperus virginiana* L. has differentiated into five geographic races, and two of these races, called Typica and Ozark, were described in detail. Typica is known to the horticulturist as the Eastern form and may be characterized as the very tall, narrowly pyramidal tree found from Virginia to southern Illinois. Within its present distribution Typica is concordantly variable, and at least so homogeneous that it seems to be carrying no introgressant genes from other species. The influence of Typica in the juniper populations of the Ozark Plateau is not evident even though isolated plantings of this race are to be found on the western banks of the Mississippi River from St. Louis southward, usually about old farmsteads. The only other race of red cedar which occurs occasionally in the St. Louis area is the Northern, which is characterized by high frequencies of the spire-like form known as var. *crebra*, by crooked fruiting peduncles, and a preference for well-drained, sandy soils with a slightly acid reaction. I postulated that this Northern race may be the consequence of a few genes from *J. horizontalis* becoming stabilized in red cedar. The Northern race, with its tendency toward suppressed lateral branching, follows the glacial drift down the Mississippi River, and where the periglacial loess occurs these junipers are abundant. South of the loess deposits, particularly in the vicinity of St. Louis, juniper populations closely resembling the Northern race occur sporadically.

The Ozark race is indeed the most abundant and important in the St. Louis area and represents red cedar throughout the Southwest. The Ozark race, which is the result of introgression by genes of *J. Ashei* Buchholz into *J. virginiana* L., includes a highly variable assemblage of junipers distributed from central Texas across eastern Oklahoma and the Boston Mountains of Arkansas through the Missouri Ozarks to the Mississippi and Missouri rivers. Introgression by genes of *J. Ashei* into red cedar has probably occurred repeatedly, at least during the Pleistocene, and current mixing is evident in restricted areas where extensive hybrid swarms exist.

The purpose of this investigation was to determine the differences between the habitats in relation to the differences in the variability within and between populations of these Northern and Ozark races of junipers. The habitats studied are close together, less than a mile apart, and are surrounded by many hundreds of populations of junipers both large and small. It was thought that these habitats may select from this large gene pool adaptive genotypes which may vary from population to population proportionately to the habitat differences.

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## ACKNOWLEDGMENTS

In the spring of 1952 I was granted a leave from the Cranbrook Institute of Science to be a guest lecturer in Genetics and Evolution at the Henry Shaw School of Botany, Washington University, St. Louis, Missouri, and to take over Dr. Edgar Anderson's class during his absence. This study was part of a project undertaken by Dr. Anderson's class under my direction.

I am most grateful to Dean Henry N. Andrews for his advice and cooperation and to Dr. Anderson for his enthusiasm in regard to field studies as well as his helpful criticism. The study was carried out in the native tracts of the Missouri Botanical Garden Arboretum, Gray Summit, Missouri, which is approximately forty miles southwest of St. Louis on US Highway 66. I am especially grateful to Mr. August P. Beilmann, Superintendent of the Arboretum, for his cooperation and detailed knowledge of land use in the Ozark region.

## GENERAL DESCRIPTION OF THE AREAS

The areas studied are within the Missouri Botanical Garden Arboretum, which is situated 40 miles southwest of St. Louis, Missouri, just south of the junction of Highway 66 and Highway 50 near Gray Summit, a hilly region principally of weathered dolomitic limestones in the northern portion of the Ozark highland. The climate is designated by Thornthwaite as BB'r (humid, mesothermal, with precipitation adequate at all seasons). Records in St. Louis for the past hundred years show such variations in precipitation that no general trends are evident, so that it is difficult to judge whether climatic amelioration or deterioration is in process. The Ozark Plateau is a part of the Oak-Hickory Forest Region described by E. Lucy Braun (1950) as the Interior Highlands, Southern Division, which lies essentially south of the glacial border. Braun wrote:

"The Southern Division is characterized by the prominence of southern species of oaks and hickories, as *Quercus stellata*, *Q. marilandica*, *Q. shumardii* (and var. *Schneekii*), and *Carya Buckleyi* (var. *arkansana* and var. *villosa*), and in the bottomlands, *Q. nigra*, *Q. lyrata*, *Carya Pecan*, *C. myristicaeformis*, and *C. aquatica* . . . . Prairie openings, limestone glades, and balds locally interrupt the forest cover."

Those who know the Ozark landscape consider these local interruptions of forest cover as the particular mark of beauty of the uplands, and the "openness" was a major feature in selection for settlement in pioneer days. Visitors to the Ozarks from foreign countries usually are most impressed by the red cedar glades which are island playgrounds in the present-day dense oak woods. In the proper season these open areas serve as edge for much wildlife activity, and perhaps the most characteristic features in this wise are the summer call of the chuck-will's-widow and the "booming" of the nighthawk that so often chooses a glade for his target.

The soils indicate a long history of open conditions where prairie vegetation, probably maintained by fire and grazing, played a very important role in the development of soil horizons. Soils in the area are characteristic of prairie-forest

transition regions and are much like the nut-structured prairie-forest Good soils of continental sub-humid steppes, being intermediate between chernozems and podzols. Regardless of its history of prairie development, the Ozark region has a forest climate and probably has had since the end of the xerothermic period. Thus the climax plant formation, which is of course subject to continual change, may be the oak-hickory forest which has been spreading extensively throughout Missouri roughly in the last hundred years. Beilmann and Brenner (1951) and Etter (1953) report this trend in their studies of Ozark vegetation. It is not likely that any region has ever had a vegetational mantle entirely in equilibrium with climate alone, for other factors affecting balance are legion—e. g. nature of geological substrate, grazing and browsing, fire, and man. Rather, as Sauer (1950) has pointed out, "Plant associations are contemporary expressions of historical events and processes, involving changes in environment and biota over a large span of geologic time." However, Braun (1950) stated that knowledge of these historical events and processes is very scant even though general trends seem to be quite clear.

The history of land usage in the Gray Summit area is not known in detail, but titles to land were granted beginning about 1850, nearly 50 years after the first settlers, mostly French, began to locate along the major waterways in what is now Franklin County, and over 80 years after St. Louis was founded, also by the French. Evidence of timber cutting, heavy grazing and burning variously from the time of settlement until the Missouri Botanical Garden acquired the property in 1925 is clear and common. Apparently, in the days before the settlement of the region most of the timber was found on the headwaters of the creeks and was scattered, giving a prairie- or park-like aspect presumably as a result of a somewhat drier climate than today and the effects of grazing, fire, etc. The timber, where dense enough to be called woodland, was usually situated in the rough lands or dissected headwaters of the streams where it was largely safe from fire.

Today the Ozarks are well covered with close forests, and the once open areas show signs of rapid forest encroachment; old fields develop rapidly to forest, but the glades show little invasion by woody species even when protected from fire or grazing. Steyermark (1940) made a vegetational survey of Missouri which covered fifteen years of extensive observation, and even though the survey was strictly qualitative it was detailed enough to permit rough comparisons with present-day conditions. He stressed the role of rock strata and soil, i. e., edaphic factors, in determining the distribution of plant associations. He described six plant associations and many more associates based on differences in soil, slope, and water availability; in his conclusions he favors the polyclimax concept subscribed to by Domin, Gams, Gleason, Tansley, and Du Rietz. He indicated that the glade flora was the result of edaphic factors, and in most sites would eventually support a maple-white oak association which in the Ozarks seems to be restricted to slopes and bluffs with neutral to alkaline soils underlain by limestone.

*The Glade.*—The Glade, which is one of several within the boundaries of the Missouri Botanical Garden Arboretum, may be characterized as a small open space

(open glade), approximately 60,000 square feet in extent, covered by grasses and junipers surrounded by a closed area (closed glade), or buffer, approximately fifty feet in width, chiefly composed of junipers and chinquapin oaks and situated on a west-facing slope (upward ENE,  $10^{\circ}20'$ ). The area studied constituted a rectangle  $400 \times 150$  feet, approximately the total extent of the open glade. In this study the term Glade refers to the open glade within the enclosure studied.

This same glade was described by Erickson, Brenner, and Wraight (1942), who demonstrated a direct correlation between the structure and composition of the glade flora and the occurrence of a dolomite stratum at or near the surface. The glade soil is very shallow (averaging about 4 inches), organically rich and derived from a dolomitic rock which under the open glade is a thin, porous dolomite locally known as "cotton-rock," an upper stratum of the Cotter Formation, and lies unconformably on the Jefferson City Formation, both in the Canadian Series of the lower Ordovician. Under the closed glade a less porous dolomite with lower magnesium content is covered by a fairly thin mantle of Union Silt Loam. The dense oak-hickory upland forest on the Union Silt Loam gives way to red cedar-chinquapin oak forest at the periphery of the glade, but wherever the "cotton-rock" occurs it drains the area sufficiently that the red cedar-chinquapin oak forest is fairly well stabilized. In winter and spring, as a consequence of greater precipitation and less evaporation, the open glade ("cotton-rock" stratum) is wet, often with standing water, while in summer and fall, when precipitation effectiveness is least, the porosity of the rock permits rapid drainage which results in rather extreme dryness in the upper few feet of the stratum. I have been frequently observing several of these glades since 1947, and, besides the rather obvious seasonal cycle of wetness and dryness, there are fluctuations every few years which markedly affect the population density of the species and the cover. In order for the perennials, in particular, to be successful in the glade community, they must be able to withstand fairly great fluctuations of the environmental conditions.

*The Old Field.*—The Old Field is situated on a gently sloping knoll below the orchid greenhouse. The upward slope ( $5^{\circ}10'$ ) is NNW facing SSE. The knoll is covered by Union Silt Loam and probably will eventually support an oak-hickory forest. On this knoll a plot 60,000 square feet in extent was laid out as a rectangle  $300 \times 200$  feet.

Prior to 1925 the area was under cultivation in the traditional "Ozark fashion." A few acres of beans, peas, and corn were planted, rows running uphill, and tilled by means of the mouldboard plow and mule driven by a tenant farmer. In 1925, when the property was acquired by the Arboretum, this field was badly eroded and almost bare of vegetation, but since 1925 it has not been grazed or burned, and the revegetation has been accomplished in the last 28 years.

At present, the arborescent growth on the Old Field consists of scattered junipers, black oak, white ash, and thickets of red elm. Wisteria is an abundant shrub,

having invaded the field from plantings nearby. The upper edge of the sloping field supports a growth of sugar maple, white ash, black oak, shingle oak, post oak, black cherry, smooth sumac, buckbrush, and poison ivy. The middle portion of the field consists of thickets or clumps of red elm saplings with a maximum height of about ten feet, and a thick growth of smooth sumac and wisteria. On the lower slope which drains into a tiny creek are growing black oak, white ash, northern red oak, persimmon, rough-leaved dogwood, winged sumac, poison ivy, woodbine, and summer grape.

The oldest arborescent growth is made up of persimmon, post oak, black oak, and shingle oak, which apparently invaded the field approximately five years after its abandonment. Then northern red oak, sugar maple, white ash and red cedar came in six to eight years after abandonment. At any rate, the older specimens of red cedar were twenty years old, eight years having elapsed since abandonment of the field. The rate of invasion by red cedar depends on the balance of several variables such as the number and proximity of seed-producing plants, condition of the invaded area, amount of cover, slope, pH, etc. Drew (1942), in his studies of abandoned crop-land in the Cedar Creek area, Boone and Callaway counties, Missouri, found that five years after abandonment sassafras, persimmon, shagbark hickory, post oak, and shingle oak invaded; after six to seven years, American elm; after eight to ten, northern red oak, sugar maple, white ash, honey locust, and black walnut; after eleven to twelve years, red cedar and black oak.

In the herb layer the general cover consisted of fairly evenly distributed clumps of broom-sedge with Kentucky blue-grass in swales and level places bordered by clumps of little blue-stem. On the up-slope, broom-sedge, tall red-top, Canada goldenrod, and old field goldenrod were conspicuous. From midway to the bottom of the slope were these same species plus dewberry (*Rubus flagellaris*) and *Aster pilosus*. Here and there were almost bare sandy slopes, a few feet in extent, consisting of stands of triple awn-grass with a few lichens and mosses. Directly beneath the crowns of most of the larger trees were areas covered by lichens and mosses.

*Cedar Hill.*—Another old field, here called Cedar Hill, is an enclosure with a gentle slope from west to east mowed annually with a sickle-bar and covered with well-spaced red cedar, black oak, black cherry, honey locust, and red elm. The shrub layer consists of dewberry (*Rubus flagellaris*), smooth sumac, trumpet-vine, buckthorn, aromatic sumac, large clumps of buckbrush, partridge pea, and seedlings of sassafras, shingle oak, and persimmon. The herb layer consists principally of Canada blue-grass, triple awn-grass, tall red-top, *Panicum capillare*, and frequent clumps of broom-sedge, scattered clumps of little blue-stem, and occasional clumps of mountain mint and ironweed. Dewberry (*Rubus flagellaris*) was scattered fairly evenly throughout the field.

The junipers average about 30 feet in height and thirty years of age, somewhat younger than those of the Glade. The juniper reproduction in the enclosure was

negligible. Although there were abundant seedlings, particularly at the edge of the crowns of those mature junipers bearing berry-cones, all were below sickle-bar height and usually under three years of age. Just outside the enclosure and in the general area juniper reproduction was very good, and ages up to thirty-five years were represented. Species composition was not analyzed because of the artificial situation. In the meadow the juniper population in an area of 60,000 square feet was sampled. In general features this meadow is closely similar to the Old Field. The soil is Union Silt Loam but much deeper since Cedar Hill lies above an old river channel. The Cedar Hill population was included in this study because of its intermediate position morphologically between the Glade junipers and those of the Old Field.

#### METHODS OF STUDY

Several factors were studied for the Glade and Old Field in order to make comparisons. Species composition, distribution of juniper seedlings, and the population structure of junipers were studied, and the data appear in Tables I-II, figs. 1-3, and pls. 20-21. Frequency was used as a quick method of measuring species composition. The Glade and the Old Field were divided into four plots by staking out the diagonals. Along the diagonals alternating from one side to the other, 20 quadrats (1 meter in size) were laid out, equally spaced from the center. Preliminary work was done in late spring of 1952, but other surveys were made in late spring and late summer of 1953. The presence of species in each quadrat was tabulated and the results for the Glade and Old Field appear in Table I. The areas studied seemed sufficiently homogeneous for the use of 1-meter quadrat size, specifically to determine the species composition of the herb layer. A sample area about 0.5 per cent of the total was used. A compromise in favor of a small sample area was made because of the limited time the class could be in the field.

Variations of the juniper populations were measured by pictorialized scatter diagrams as demonstrated in *Juniperus* in a previous paper (Hall, 1952). Five characters were scored: gland length-width ratio; length of whip (longshoot) leaf; length of terminal whip; length of lateral whip; on secondary shoots, the per cent of tertiary branches which have the decussate leaf arrangement. Two of these characters were also analyzed by use of the parameters of the log-normal curve which the data fit. These data, when plotted on logarithmic probability paper, result in a straight line.

In an attempt to get some estimate of seed-dispersal pattern, the distribution of seedlings was studied. Observations were made to determine the role that birds, mammals, and gravity may play in seed dispersal.

#### SPECIES COMPOSITION

Rough comparisons were made of species composition of vascular plants for the Glade and the Old Field. Only one quadrat size was used and no attempt was made to obtain quantitative data on density or cover. For convenience a frequency index after the method of Raunkiaer (1918) was made up for the Glade and the

Old Field. The percentage of frequency for a given species is the percentage ratio the plots on which the species occur bear to the whole number of plots sampled. Raunkiaer found that the greatest number of species had the least frequency; and that as the frequency increased the number declined steadily, until at the highest frequency the number increased slightly. Raunkiaer used five frequency groups, A, B, C, D, and E, designating the species of frequency 1-20 per cent, 21-40 per cent, 41-60 per cent, 61-80 per cent, 81-100 per cent, respectively. His law of distribution, determined from quadrat studies in Europe was  $A > B > C \geq D < E$ ; the actual percentages were approximately 53, 14, 9, 8, 16. In eastern America, Kenoyer (1927), found that 69, 12, 6, 4, 9 per cent were more characteristic.

In this study the Glade had a frequency index of 28, 8, 2, 2, 2 or  $A > B > C = D = E$ . This index is similar to that found by Kenoyer in his studies for America and indicates a fairly high proportion of sporadic species and a very few acting in a "dominant" role. The Glade has uniformly distributed patches of *Sporobolus neglectus*, and the size of each patch fluctuates somewhat from year to year. When the patches are smaller, more *Bouteloua curtipendula* and forbs are in evidence. In good years the Glade has a good cover contributed principally by a very small number of species even though there is an appreciable number of sporadic species between the clumps of the cover plants.

The Old Field index was 22, 3, 8, 5, 0 or  $A > B < C > D > E$ . This somewhat irregular result is a product of the heterogeneous nature of the Old Field flora. There are a large number of sporadic species, a fairly large number of species intermediate in frequency, and no "dominants." The floral composition and vegetational structure are markedly different from those of the Glade. Factors of competition and selection are less delicately balanced in the Old Field, and these factors undoubtedly cause the population structure of the junipers there to be different from that of the Glade.

Table I lists the species and their frequencies found in sampling 0.5 per cent of the area studied. Only the under-story is represented. Woody plants in the list were seedlings or sprouts in size class 1 (0-0.9 feet) of Weaver and Clements (1938). The Old Field had seven species of woody plants represented in this size class for the area surveyed, which compares with nine species of similar size found by Drew (1942) to be common in old fields twenty-five years after abandonment. In the Old Field all sizes of woody plants were abundant up to size class 4 (3.6-9.5 inches D.B.H.), but on the Glade very few specimens larger than size class 1 were seen, suggesting a high seedling mortality. The frequency data in Table I show that the Glade and Old Field are quite different in species composition and suggest a difference in the pattern of succession. The Glade is a "prairie" association with *Andropogon scoparius* and *Rudbeckia missouriensis* contributing most to its aspect and with *Andropogon scoparius* and *Sporobolus neglectus* contributing most to the cover. Even though there is some fluctuation in abundance from year to year, there are definite dominants, a good variety to the flora, and a stability in its overall composition which suggests that succession is very slow and that the Glade

TABLE I  
SPECIES LIST WITH FREQUENCIES FOR UNDER STORY OF GLADE AND OLD FIELD\*

Glade	Frequencies	Old Field
1. <i>Sporobolus neglectus</i>	1.00	
2. <i>Carex Crawei</i>	.90	
3. <i>Andropogon scoparius</i>	.80	<i>Poa pratensis</i>
4. <i>Houstonia longifolia</i>	.75	<i>Rubus flagellaris</i>
5. _____	.70	<i>Andropogon virginicus</i>
6. _____	.70	<i>Aster pilosus</i>
7. _____	.65	<i>Desmodium glabellum</i>
8. <i>Euphorbia corollata</i>	.60	
9. <i>Rudbeckia missouriensis</i>	.55	<i>Rumex bastatulus</i>
10. _____	.55	<i>Oxalis stricta</i>
11. _____	.50	<i>Panicum virgatum</i>
12. _____	.50	Lichens
13. <i>Sisyrinchium campestre</i>	.45	<i>Erigeron strigosus</i>
14. _____	.45	<i>Taraxacum officinale</i>
15. _____	.45	<i>Hieracium Gronovii</i>
16. _____	.45	<i>Campsis radicans</i>
17. <i>Hypericum prolificum</i>	.40	<i>Triodia flava</i>
18. <i>Gaillardia pulchella</i>	.40	
19. <i>Echinacea pallida</i>	.40	
20. <i>Ruellia humilis</i>	.35	
21. <i>Oenothera missouriensis</i>	.35	
22. <i>Heliotropium tenellum</i>	.35	
23. _____	.30	<i>Achillea millefolium</i>
24. <i>Viola pedata</i>	.25	<i>Parthenocissus quinquefolia</i>
25. <i>Selaginella rupestris</i>	.25	Mosses
26. <i>Juniperus virginiana</i>	.25	
27. <i>Viola papilionacea</i>	.20	<i>Ulmus rubra</i>
28. _____	.20	<i>Celtis occidentalis</i> var. <i>pumila</i>
29. <i>Coreopsis lanceolata</i> var. <i>villosa</i>	.15	<i>Hypericum punctatum</i>
30. <i>Ulmus rubra</i>	.15	<i>Prunus serotina</i>
31. _____	.15	<i>Cercis canadensis</i>
32. _____	.15	<i>Rhus aromatica</i>
33. Mosses	.10	<i>Juniperus virginiana</i>
34. <i>Eleocharis compressa</i>	.10	<i>Asplenium platyneuron</i>
35. <i>Aster oblongifolius</i>	.10	<i>Ambrosia artemisiifolia</i>
36. <i>Zizia aurea</i>	.10	<i>Allium vineale</i>
37. <i>Monarda citriodora</i>	.10	<i>Solanum carolinense</i>
38. <i>Cercis canadensis</i>	.10	<i>Carex Haydenii</i>
39. <i>Rhamnus caroliniana</i> var. <i>mollis</i>	.10	<i>Eragrostis spectabilis</i> var. <i>sparsibirsuta</i>
40. <i>Comandra Richardsiana</i>	.10	
41. <i>Lotus americanus</i>	.10	
42. <i>Orobancha uniflora</i>	.10	
43. <i>Acalypha graciliens</i>	.10	
44. <i>Panicum virgatum</i>	.10	
45. <i>Triodia flava</i>	.05	<i>Veronica arvensis</i>
46. Lichens	.05	<i>Asclepias syriaca</i>
47. <i>Bumelia lanuginosa</i> var. <i>oblongifolia</i>	.05	<i>Acer saccharum</i>
48. <i>Fraxinus americana</i>	.05	<i>Physalis pruinosa</i>
49. <i>Monarda Russeliana</i>	.05	<i>Pentstemon pallidus</i>
50. <i>Acer saccharum</i>	.05	<i>Sporobolus neglectus</i>
51. <i>Anemonella thalictroides</i>	.05	<i>Daucus pusillus</i>
52. <i>Bouteloua curtipendula</i>	.05	<i>Antennaria fallax</i>
53. <i>Silphium laciniatum</i>	.05	<i>Potentilla recta</i>
54. <i>Pterocarya esculenta</i>	.05	<i>Galium aparine</i>
55. <i>Quercus Muehlenbergii</i>	.05	<i>Poa compressa</i>

Glade	Frequencies	Old Field
56. <i>Pellaea atropurpurea</i>	.05	<i>Rhus Toxicodendron</i>
57. <i>Fimbristylis Drummondii</i>	.05	_____
58. <i>Petalostemum purpureum</i>	.05	_____
59. <i>Symphoricarpos orbiculatus</i>	.05	_____
60. <i>Pentstemon pallidus</i>	.05	_____

\* Nomenclature after Gray's Manual of Botany, 8th edition, 1950.

community is one of real integrity. Because of the uniformity in distribution of *Andropogon*, *Sporobolus*, and *Bouteloua* the quality of the cover on the Glade can be determined fairly well with frequency data. In a good year the clumps of *Andropogon* are larger, denser, and more frequent. The *Sporobolus* effectively fills in between the clumps. In a dry or unseasonable year the *Andropogon* may lose ground, the *Sporobolus* to a lesser extent, but the *Bouteloua* may increase considerably. Thus, one can tell when the Glade is in good condition, so far as climatic fluctuations are concerned, by the relative frequencies (or preferably cover) of *Andropogon scoparius* and *Bouteloua curtipendula*. I think the Glade's general aspect and its severe selection against trees, shrubs, and woodland herbs, particularly as evidenced by selection against all but very *Ashei*-like junipers, support the conclusions of Erickson, Brenner, and Wraight (1942) that these glades are edaphic sub-climaxes.

The frequency data show the Old Field to be fairly typical for the Ozarks. There are several abundant species, but none of these contribute decisively to the field's aspect or cover. *Poa pratensis*, *Andropogon virginicus*, *Panicum virgatum*, *Triodia flava*, and *Rubus flagellaris* are conspicuous. While the number of species is much the same for the two areas, the Old Field has fewer species with high frequencies or very low frequencies, and more with average frequencies. The Old Field is obviously in a rapid stage of succession toward woodland.

Several other species were not found in the quadrats sampled. Mostly, these are not common plants in these areas but in some cases may occur with frequencies of 5 or 10 per cent in localized areas of the Glade or Old Field. The following species occurred on the Glade but did not occur in the quadrats: *Ulmus rubra*, *Celtis occidentalis*, *Physocarpus opulifolius*, *Amelanchier arborea*, *Rosa carolina*, *Prunus serotina*, *Rhus glabra*, *R. aromatica*, *Ilex decidua*, *Celastrus scandens*, *Acer saccharum*, *Cornus Drummondii*, *Diospyros virginiana* var. *pubescens*, *Fraxinus quadrangulata*, *Viburnum rufidulum*, *Sporobolus heterolepis*, *Elymus virginicus* forma *hirsutiglumis*, *Allium stellatum*, *Menispermum canadense*, *Psoralea psoraloides* var. *eglandulosa*, *Linum sulcatum*, *Petalostemum purpureum*, *Croton monanthogynus*, *C. capitatus*, *Asclepias tuberosa* ssp. *interior*, *Triosteum perfoliatum*, *Vernonia crinita*, *Kubnia eupatorioides* var. *corymbulosa*, *Hypericum perforatum*, *Amsonia illustris*, *Isanthus brachiatus*, *Ruellia humilis*, *Solidago rugosa* var. *aspera*, *S. rugosa* var. *celtidifolia*, *S. nemoralis*, and *Parthenium hispidum*. A

total of 80 species of vascular plants was collected on the Glade (45 from the quadrats; 35 by systematic search). Eighteen other species, mostly seedlings of the woody species already mentioned, were found in the Old Field but not in the quadrats. According to experience and estimates, it seems likely that slightly over 100 species may be found in similar areas the size of the Glade and Old Field. Since these studies did not run continuously through the seasons involved, a considerable number of species was probably missed. It is also obvious from the data that a sampling area 0.5 per cent of the total is too small for best results; an area between 1 and 2 per cent would have been effective.

The closed glade is a tension zone between the open glade and the oak-hickory woodland. It is a mixture of the open glade and oak-hickory woodland floras, but most of the cover in the arborescent layer is from juniper and chestnut oak. The transition from one community to the other seems abrupt since it occurs over a short distance, usually from 50 to 100 feet. From transect studies in the closed glade I listed 75 species, 39 of which were frequent species in the oak-hickory woodland and 43 were frequent in the open glade (Glade).

Plate 20 shows the aspect of the Glade with close-ups of two quadrats (1 meter in size) on the up-slope and two on the down-slope. Plate 21 shows the Old Field aspect with two quadrats up-slope and two down-slope.

#### DISTRIBUTION OF JUNIPER SEEDLINGS

The diagonals and sides of the Old Field and the Glade were used as transects for seedling counts. All juniper seedlings were counted within one-half meter on either side of the diagonals and one meter to the inside of the area boundaries. Seedlings were divided into three classes as follows: Class 1, 18 inches or less; Class 2, 18.1–36 inches; Class 3, 36.1–72 inches. Total number of seedlings reported is based on counts in approximately one twentieth of the total area.

In the Old Field, a total of 621 seedlings was estimated, of which 276 were in Class 1, 207 in Class 2, 138 in Class 3. The actual number is probably somewhat higher since the smaller seedlings are rather easily overlooked. The seedlings were not distributed at random, but were either clumped about the mature (fruiting) female trees (with over 90 per cent of them on the down-slope side), or were more or less aggregated at the bottom of the slopes or in other areas where materials carried by run-off water are deposited. Birds play an important role in the distribution of seedlings in the Old Field. Many young seedlings were clustered below the branches of shrubs and trees other than junipers. A very few were found on isolated knolls and in the open where they may have been deposited by birds in flight or by ground-feeding birds.

The Glade supported a great many more seedlings under four years of age than did the Old Field. The estimate was: Class 1, 6,672; Class 2, 10; Class 3, 12. The total estimate was 6,764 seedlings for the 60,000 square feet of glade enclosure. These were distributed much as in the Old Field, but even more uniformly because of the greater uniformity of the 10° slope characterizing the Glade. The seedlings

were either clumped on the down-slope side of the mature (fruiting) female trees or were aggregated at the bottom of the Glade slope where the *Sporobolus neglectus*, because of its increasing cover toward the lower edge, acted as a brake to tumbling berry-cones carried by run-off water. There were numerous seedlings in the open, probably from seeds deposited by birds. Great flocks of robins and cedar waxwings are a common sight on the glades, particularly in the fall after the crop of berry-cones has ripened. Fortuitous fluctuations in climate probably add to the seedling mortality. In very wet seasons the seedlings with more genes of red cedar are probably favored only to be wiped out in a later year by drought. Likewise, seedlings possessing a strong *J. Ashei* component are favored in drought seasons but may suffer defeat in wetter periods.

#### POPULATION STRUCTURE OF JUNIPERUS

The variations in the junipers (*Juniperus virginiana*) of the Glade, Old Field, and Cedar Hill were studied, and five morphological characters were measured and plotted as pictorialized scatter diagrams. Two of the five characters, measured, gland length-width ratio and lateral whip length, were used on the ordinate and abscissa of logarithmic paper ( $1 \times 1$  cycle) and the other three as rays on the scatter diagrams. The data for the three characters plotted as rays were grouped as follows: (1) whip-leaf length: long-bar = 8 mm. or more, half-bar = 5-7 mm., no bar = 2-4 mm.; (2) per cent decussate: long-bar = 25-100 per cent, half-bar = 6-24 per cent, no bar = 0-5 per cent; (3) terminal whip length: long-bar = 80 mm. or more, half-bar = 31-79 mm., no bar = 0-30 mm. The scatter diagrams for the Glade, Cedar Hill, and the Old Field populations, as well as for populations typical for the species, are shown in fig. 1.

Population means and ranges were obtained from the grouped data (pictorialized scatter diagrams) in the manner described in an earlier paper (Hall, 1952, p. 53). The numbers given have no absolute value but represent a graded scale or index of characteristics. The scale is made up in such a way that low scores belong to *J. Ashei*, high scores to *J. virginiana*, and intermediate scores to morphological intermediates or introgressants of the two species. From these scatter diagrams the following population means on this arbitrary scale were obtained: Glade—4.35; Cedar Hill—5.48; Old Field—10.0. Typical *J. Ashei* has a population mean of 2.0-2.3; typical *J. virginiana*, Eastern race, has a mean of 9.0-10.0.

The two characters plotted on the abscissa and the ordinate for the pictorialized scatter diagrams were also analyzed by using ordered values. The data were expected to fit a log-normal distribution which was confirmed, for the data produced a straight-line function when the ordered values (from smallest to largest) were plotted on logarithmic probability paper. I followed the practical short-cut recommended by George W. Thomson of the Ethyl Corporation, which used the range as a measure of dispersion instead of the standard deviation. Statistical techniques using the range are particularly efficient with small samples.

This is an excellent method of checking the confidence of data where only an average and the range are available. The confidence limits  $a, b = \bar{x} \pm ts/\sqrt{n}$ ,

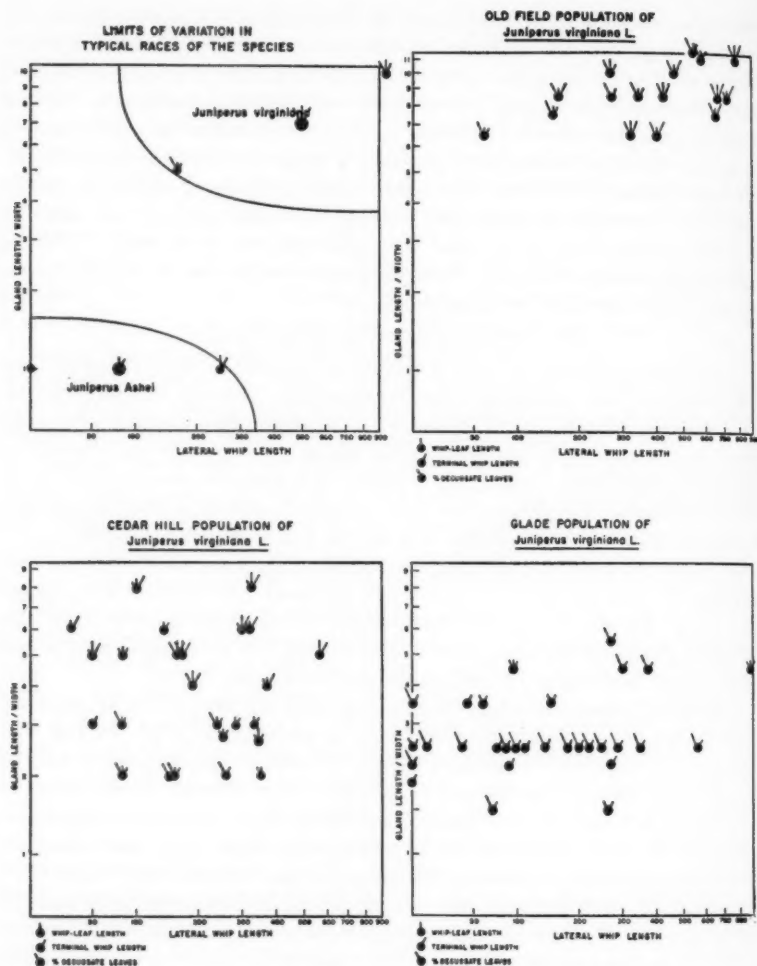


Fig. 1. Scatter diagrams showing the variations in five characters of a typical race of *Juniperus virginiana* from southwestern Virginia, a typical race of *J. Ashei* from the Edwards Plateau of Texas, and of three populations of *J. virginiana* at Gray Summit, Mo. The diagram at the upper left for the typical races shows the means (large dots), the extremes (small dots), the limits of variation (the curved lines). (The symbol in the space at the upper right of this diagram should have had three long arms.) In the diagrams for the three Gray Summit populations each dot represents a single individual.

where  $\bar{x}$  is the mean,  $t$  is Student's  $t$ ,  $s$  is the square root of the estimated population variance, and  $n$  is the number in the sample. Or, by using the short-cut the 95 per cent confidence limits are equal to the range multiplied by the proper value<sup>1</sup> (0.1064 for  $n = 25$ , 0.0720 for  $n = 42$ ) plus or minus the mean.

Table II lists the population means, confidence limits, and standard deviations (log values) for two characters of each of the three populations and typical populations of both *J. Ashei* and *J. virginiana*. Figure 2 represents the ordered values plotted on logarithmic probability paper. The slopes of the lines depend on the amount of variation within each group; the greater slopes indicate the more heterogeneous populations. The point of intersection of each line with the 50 per cent value is the estimated mean for each population. The points of intersection of the 25 per cent and 75 per cent values with each line delimit the range where half the values for that character will probably lie. In fig. 3 rectangles are made about the means to correspond to the 50 per cent probability level, and the farther two rectangles are separated the greater the probability that the difference between the corresponding means is not due to chance. The dotted lines indicate the 95 per cent confidence limits of the means from Table II.

These five populations were compared to determine the probability that they represent the same population with equal means by means of the  $t$ -test. If one assumes the means of two populations to be equal, the sample difference is tested to see whether it is no more than sampling variation from the hypothetical difference, zero. Each of these comparisons led to a large  $t$  value, indicating a low probability that they represent samples from a single population. Welch's modification of the  $t$ -test was used for the comparison because the variances were not homogeneous (Comparison of  $\mu_1 - \mu_2$  regardless of  $\sigma_1^2/\sigma_2^2$ ).

TABLE II

MEANS AND THEIR 95 PER CENT CONFIDENCE LIMITS FOR TWO CHARACTERS IN FIVE POPULATIONS OF *JUNIPERUS*

Populations	Age Class	Number in sample	Whip leaf length (mm.)			Gland length/width		
			Means	Conf. limits	Stand.* dev.	Means	Conf. limits	Stand.* dev.
<i>J. Ashei</i>	30 yrs.	25	4.8	(4.0-5.7)	0.179	1.0	(0.95-1.05)	0.045
Glade	35 yrs.	42	2.6	(2.3-3.0)	0.500	2.2	(2.0-2.5)	0.145
Cedar Hill	30 yrs.	25	6.8	(5.9-8.0)	0.522	3.9	(3.4-4.5)	0.187
Old Field	20 yrs.	25	7.2	(6.3-8.3)	0.140	8.1	(7.6-8.8)	0.093
<i>J. virginiana</i>	30 yrs.	25	8.8	(8.1-9.6)	0.088	6.4	(6.0-6.9)	0.100

\* Log values.

<sup>1</sup>See the Appendix to this paper. The values for these multiplying factors were worked out for sample numbers from 2 to 1000 by George Thomson and appear in Table III.

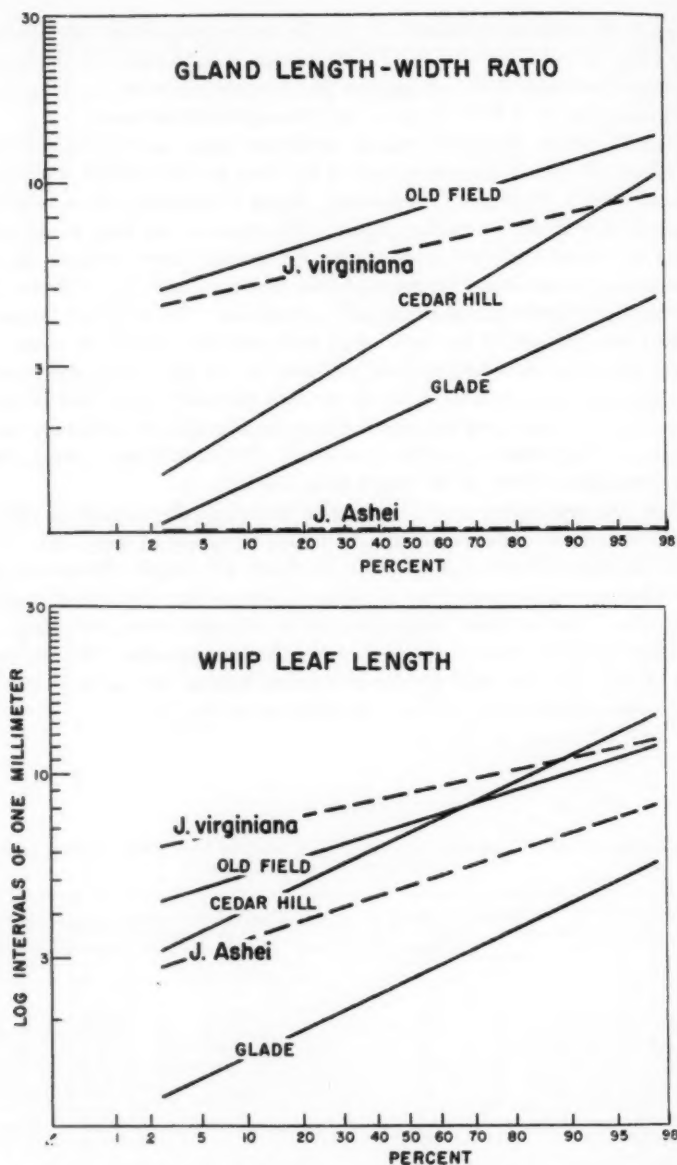


Fig. 2. Ordered values, plotted on logarithmic probability paper, for two characters for typical populations of *Juniperus virginiana*, *J. Ashei*, and the three populations of *J. virginiana* from Gray Summit. Length of the lines delimit the range where 95 per cent of the values for these two characters will probably lie.

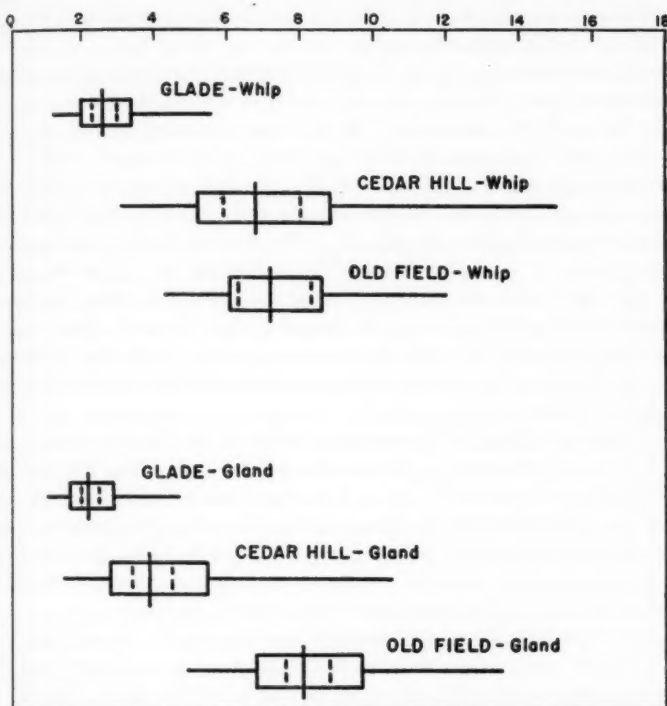


Fig. 3. Variation in whip leaf length and gland length-width ratio in the three populations of *Juniperus virginiana* from Gray Summit, Mo. The estimated means are represented by vertical bars; the 95 per cent confidence limits of the means by vertical dashes; the rectangles delimit the ranges where 50 per cent of the values will probably lie; the length of the horizontal lines delimit the ranges where 95 per cent of the values will probably lie.

#### DISCUSSION

In the Missouri Botanical Garden Arboretum at Gray Summit, Missouri, these three populations of *Juniperus virginiana* called here Glade, Cedar Hill, and Old Field, are each distinct, having considerably different variances and significantly different means. Each is also distinct from either species, *J. Ashei* or *J. virginiana*, which contribute to the variability of these Ozark populations. Yet, these three Ozark populations exist within less than a mile of one another, but in habitats which, at least in part, may be noted for their differences more than their similarities. In the sums of several morphological characters these populations differ from one another in nearly the same degree, so that a crude ranking using five characters

gives arbitrary values of 1.0 for *J. Ashei*, 2.1 for Glade, 3.0 for Cedar Hill, 4.0 for Old Field, 4.9 for *J. virginiana*.

Where each character is compared separately there is greater apparent difference between populations. Methods utilizing several characters therefore give a more accurate picture of the population. With several characters plotted, scatter diagrams give a good impression or "bird's eye view" of the variation within a population even though statistical inferences may not be drawn from them alone. When the populations are compared character for character, one finds that the degree of difference between characters is not necessarily similar for each character. The Glade population may closely resemble Cedar Hill in one character and more closely approach *J. Ashei* in another. Unequal variability, character for character, is characteristic of species hybrids and introgressant populations. Even when considering variation within the individual, most naturalists know that hybrids, particularly in wide crosses, have more intra-individual variability than do more typical plants of the species.

The Glade and Cedar Hill populations, both of the Ozark race, i. e. introgressants of *J. virginiana* by *J. Ashei*, are the most variable. The Old Field population is a mixture of the Ozark race and the Northern race (including var. *crebra* type) of red cedar; but as far southwestward as Gray Summit, Missouri, it occurs sporadically in disturbed habitats where the soil is sandy, light, and well drained. I have not yet seen this northern invader on a glade even though it could conceivably occur there within a favorable micro-habitat.

The Old Field and Cedar Hill habitats are very similar in every aspect but history of use by man. The Old Field was allowed to erode severely, and consequently it has less topsoil and organic matter than the Cedar Hill. The Old Field soil is more acid, sandy and coarser than Cedar Hill soil. Both Old Field and Cedar Hill soils are quite different from the very thin, organically rich, spring-wet, summer-dry soil of the Glade.

The Northern race of red cedar (including var. *crebra*) tends to be arenicolous, and even though it develops well on sandy areas overlying limestone or on the strands of marly lakes, it does best on slightly acid, well-drained strand or dune areas where competition with other plants is at a minimum. The Northern race becomes more arenicolous as it becomes more columnar or spire-like. Because of the ease with which junipers may be distributed over great distances, it is not surprising to find an occasional mixture of the Northern race of red cedar in the northeastern Ozarks. However, its occurrence there is a result of man inadvertently preparing a suitable habitat, an eroded, acidic, sandy field with poor cover. Except for the minor role the Northern race plays in introgression with the Ozark race, its effect on the Ozark populations is transient and dependent on the perpetuation of poor land-use practices. Ozark fields which have had fair treatment, particularly where cover has been protected, support stands of the Ozark race alone. In part, the Ozark race is also dependent on man since a large number of its populations occur on cleared or grazed land.

Several other factors affect the distribution and structure of juniper populations. Some of these factors are intrinsic and some extrinsic, but it is impossible to consider them independently. Rate of reproduction, per cent viability, presence of introgressive genes, character of the climatic extremes (whether unfavorable for natural seed stratification, which seems to be the situation at the northern limits of red cedar), amount of bare area in the habitat, slope, soil conditions, presence and abundance of bird and mammal species which aid in seed dissemination, role of run-off water and gravity in seed dissemination, and several other factors occur in different combinations and degrees to produce populations ranging from uniform (as in a cedar-brake) to less uniform (apparently random) to clumped. In general, when a large enough area is examined there may be found "parent" populations consisting of cores of ancient specimens which supply or supplied the seed stock for the general area. In southwestern Missouri these mother-plants may be found on the bluffs of the White River where they have fruited for centuries safe from fire and other hazards. In northern Missouri the bluffs of the Missouri and Meramec Rivers support populations of ancients. These bluff habitats of the major rivers were probably the original environment for *Juniperus* long before the Ozark glades were first colonized by junipers.

On most of the glades in the eastern Ozarks the oldest junipers are over 100 years of age, probably between 125 and 135 years. Since all the older junipers from which increment borings were taken were hollow at the center, it was not possible to get precise ring counts, but by applying a factor determined by the rate of decrease in years per inch from the center to the outside of an increment, a good estimate of age may be made. Much older trees (judged by circumference) have been found occasionally on bluffs throughout the Ozarks, but those from which increments were taken were hollow and usually with more or less eccentric rings. Such old junipers are not found in Ozark fields. In the early years of the 19th century and previously, written accounts of travels and casual reports by geologists indicate that junipers were to be found only along bluffs of the major rivers, but reports in the last half of that century presented a picture of juniper distribution much as it is today. Wherever the rocky limestone glades are burned each year, they are devoid of junipers and shrubs, giving an open grassland aspect with an abrupt transition to forest at the edges. Also, the junipers do not easily invade a glade that has been protected from grazing and supports a good stand of grass. The treeless glades, which are not uncommon, always have good cover and protection from man's grazing animals. Where glades show signs of erosion junipers are localized. In general, juniper density is proportional to the degree of land abuse, so that glades may support junipers distributed as dense "brakes", open stands with evenly but widely spaced individuals, or scattered, clumped colonies. Because of the nature of the glades slight grazing could easily weaken the cover to permit invasion of junipers where fire-sere grassland would not be so easily weakened. Before white man came to the Ozarks, wild herds probably initiated the

invasion of the glades by junipers; white man tremendously accelerated the process through his domestic animals.

In an earlier paper (Hall, 1952) I suggested that introgression between *J. Ashei* and *J. virginiana* may have begun as early as the late glacial period, followed by an expansion during the xerothermic period. Throughout this time, before settlement of the Ozarks, the most continuous habitats for junipers were the bluffs, knobs, rough glades, and youthful streams or rivers with flood-plains in an early stage of succession. Probably continuously the bluffs, knobs, and glades (edaphic sub-climaxes) were inhabited by *Ashei*-like junipers while the streams and river banks supported scattered stands of *virginiana*-like plants.

The distribution pattern of junipers in the Ozarks has probably changed radically since settlement. It is clear that the oldest junipers are situated on bluffs or glades, while old fields in the St. Louis area may support mature colonies (oldest plants up to 70 years) of the Ozark race or occasionally more youthful colonies (40 years or less) of the Northern race mixed with Ozark. From this study and cursory examination of other fields, it is evident that the condition of the land in large part determines the kind of junipers selected from the local gene pool. Literally, explosive distribution of juniper has occurred in the last hundred years, progressively increasing in amplitude as abused or worn-out land was abandoned to old-field succession. The fact that these neighbor populations, particularly Glade and Old Field, are distinct even though intermediate does not mean that hybridization between them is limited, but that each habitat is selecting the best-adapted genotypes. Natural selection is strong enough to limit the portion of the available gene pool which may be realized. Here are two powerful forces working against one another. Strong natural selection restricts the gene pool; hybridization amplifies it. With species like those of *Juniperus*, which hybridize freely and are readily dispersed, I suggest that continuously variable habitats result in continuously variable populations, and the simplest situation is when the hybridization is between two allopatric species.

Anderson (1948) stated that hybrids between two species differing in habitat requirements are expected to occupy intermediate habitats. The  $F_1$  should occupy a habitat more or less intermediate between the two species; the  $F_2$  should occupy more variable habitats, but the range should lie between the habitats of the species; backcrosses or introgressants should occupy habitats closest to the backcross parent. Two species may be quite interfertile, exist side by side, yet show little evidence of hybridization between them because the habitats select the parent-type combinations. If the habitat is disturbed, these available mongrels may become established. The homes of these variants are the seres either initiated by natural processes or man. While hybrid swarms and hybrid habitats are transient, they have their influence toward increasing variability both through cryptic processes, e. g. structural differentiation, and toward accelerating regional differentiation. If, for the sake of discussion, man as a producer of hybrid habitats is ignored, it will be seen that processes which initiate succession produce hybrid habitats, and indeed the edges

of ecologic systems, physiographic provinces, and climatic regions are hybrid habitats. Ecologic tension zones are hybrid habitats where species which meet may develop discordant variability. When man enters the scene, the pattern becomes more complex. Hybridization may do its cryptic work in tension zones through all levels of ecologic structure. The obvious evidence of hybridization, the hybrid swarms, are transient; and they may occur whenever the right hybrid habitat is available, but in most situations the habitats select gene combinations more like the parents and tend to keep the populations distinct.

## SUMMARY

In the northeastern Ozarks *Juniperus virginiana* is represented by the Ozark race (introgressants from *J. Ashei*) on bluffs, glades, and most old fields. Occasionally, the Northern race is found locally with a little admixture of the Ozark race. Three populations of *J. virginiana* in the northeastern Ozarks were studied in detail in order to compare their variation patterns and habitats. Variation patterns were compared by means of scatter diagrams for five characters and ordered values, means, 95 per cent confidence limits, and standard deviations for two characters. The t-test modified by Welch was used to compare the means of the populations. Habitats were compared in terms of their histories, slope, soil profile, flora, frequency of species, rough estimates of cover, seedling distribution.

The evidence suggests that the three populations—Glade, Cedar Hill, and Old Field—are distinct and differ more or less proportionately to the differences in their habitats. The Glade (Ozark race) is the most southwestern in affinity, more closely resembling a population and habitat of *J. Ashei*. Cedar Hill (Ozark race) is intermediate between Glade and typical red cedar and occurs on old fields which are in good condition or, farther southwestward from Gray Summit, Missouri, on more worn-out lands. The Old Field (Northern race with a little mixing from the Ozark race) occurs on worn-out acidic and sandy lands in the vicinity of St. Louis and northeastward.

Extremely high seedling mortality (much higher on the Glade than Old Field) suggests that strong natural selection restricts the field for variability even in the face of considerable hybridization. The present balance between these two evolutionary forces depends on man making and keeping available a variety of suitable habitats. A shift in habitat qualities will result in a shift in the variation pattern of the junipers.

Distribution of age classes in the junipers indicates that the bluffs, knobs, and glades have been colonized longest by junipers, followed by the old fields supporting the Ozark race, and last the worn-out sandy, acidic fields supporting youthful colonies of the Northern race. An explosive expansion of juniper colonization resulting from man's activities seems to have occurred within the last hundred years, growing progressively as land has been worn out and abandoned. It is proposed that man is primarily responsible for the present explosive evolution in *Juniperus* in eastern North America and that if his influence were removed from

the scene, the field of variability would decline as the area of occupation contracts. Without man's help junipers would be more or less restricted to the areas in a natural state of arrested development such as the bluffs, knobs, and glades.

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## EXPLANATION OF PLATE

## PLATE 20

## Aspect of Glade

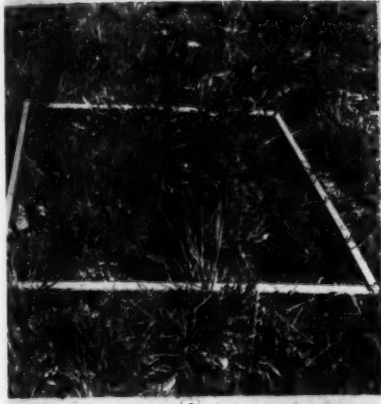
- Fig. 1. Open glade looking south.
- Fig. 2. Open glade looking north.
- Figs. 3 and 4. Two quadrats in open-glade up-slope.
- Figs. 5 and 6. Two quadrats in open-glade down-slope.



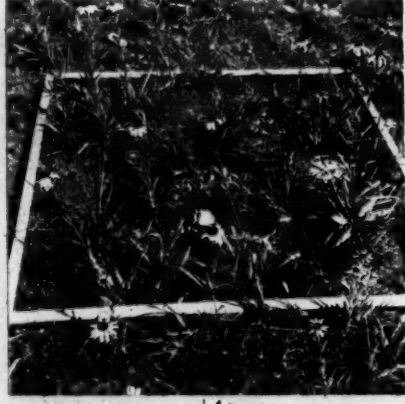
1



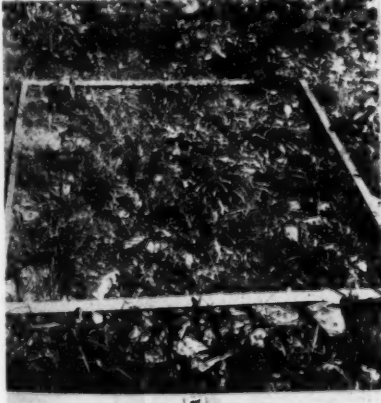
2



3



4



5



6

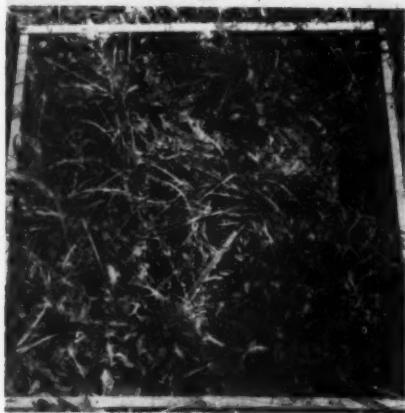
HALL—OZARK JUNIPER POPULATIONS



1



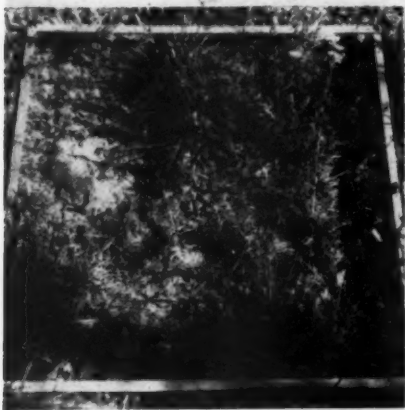
2



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HALL—OZARK JUNIPER POPULATIONS

EXPLANATION OF PLATE

PLATE 21

Aspect of Old Field

- Fig. 1. Old Field begins beyond mowed area.  
Fig. 2. Old Field, interior.  
Figs. 3 and 4. Two quadrats, up-slope.  
Figs. 5 and 6. Two quadrats, down-slope.

## APPENDIX

## ESTIMATION OF CONFIDENCE LIMITS OF POPULATION MEAN FROM RANGE

I am very grateful to George W. Thomson for the method by which 95 per cent confidence limits of the mean may be rapidly estimated by multiplying the sample range by a factor. Lord (1947) prepared a table of factors for sample sizes from two to twenty for six classes of probability (90-99.9 per cent). Thomson prepared a table of factors including greater sample sizes for 95 per cent probability. Thomson's table and brief discussion are published here for the benefit of other biologists who may wish to use this short method of getting 95 per cent confidence limits of the mean.

The usual method of estimating the variability of a population from a sample is by the use of the usual standard deviation estimator,  $s$ . However, recent research has shown that much more convenient estimates can be obtained from the sample range, which is defined to be the difference between the smallest and the largest values in the sample. These estimates are not as efficient in the statistical sense, but the loss is not important from a practical point of view. A useful by-product of this research is the rapid estimation of confidence limits of the mean of a normal population by the multiplication of the sample range by a factor. These results are associated with a smaller number of equivalent degrees of freedom than confidence limits based on the usual  $s$  estimates of the population standard deviation. A close approximation for the multiplying factors was found by Patnaik (1950) who approximated the distribution of the range in normal samples by the  $\chi$ -distribution.

If  $w$  is the range in a sample of size  $n$ , then  $w/\sigma = c \chi/\sqrt{\nu}$  where  $c$  is a scale factor and  $\nu$  is an equivalent number of degrees of freedom for  $\chi$ .

The following table extends previous calculations (Thomson, 1953) to sample sizes as large as 1000.

TABLE III  
SCALE FACTORS AND EQUIVALENT DEGREES OF FREEDOM FOR  $\chi$ -APPROXIMATION  
TO RANGE IN NORMAL SAMPLES\*

Numb. in sample $n$	Degrees of freedom $\nu$	Scale factor $c$	Equivalent two-sided 5% $t$	Confidence limits** $\pm t/(c\sqrt{n})$
2	1.0000	1.41421	12.7062	6.3531
3	1.9846	1.91155	4.3349	1.3093
4	2.9291	2.23887	3.2265	0.7206
5	3.8267	2.48124	2.8267	.5095
6	4.6772	2.67253	2.6249	.4010
7	5.4841	2.82981	2.5038	.3344
8	6.2512	2.96288	2.4233	.2892
9	6.9818	3.07794	2.3658	.2562
10	7.6798	3.17905	2.3228	.2311
11	8.3485	3.26909	2.2894	0.2112

TABLE III (Continued)

Numb. in sample <i>n</i>	Degrees of freedom <i>v</i>	Scale factor <i>c</i>	Equivalent two-sided 5% <i>t</i>	Confidence limits** $\pm t / (c\sqrt{n})$
12	8.9896	3.35016	2.2626	.1950
13	9.6057	3.42378	2.2406	.1815
14	10.1997	3.49116	2.2249	.1703
15	10.7717	3.55323	2.2067	.1604
16	11.3249	3.61071	2.1933	0.1519
17	11.8602	3.66422	2.1817	.1444
18	12.3789	3.71424	2.1715	.1378
19	12.8823	3.76118	2.1624	.1319
20	13.3723	3.80537	2.1543	.1266
21	13.85	3.847	2.147	0.1218
22	14.31	3.887	2.141	.1174
23	14.76	3.924	2.135	.1134
24	15.20	3.960	2.129	.1098
25	15.61	3.994	2.124	.1064
26	16.05	4.027	2.120	0.1032
27	16.44	4.058	2.115	.1003
28	16.84	4.088	2.111	.0976
29	17.23	4.116	2.108	.0951
30	17.63	4.144	2.104	.0927
35	19.38	4.268	2.090	0.0828
40	21.04	4.373	2.079	.0752
45	22.61	4.465	2.071	.0691
50	24.04	4.545	2.064	.0642
55	25.37	4.617	2.058	.0601
60	26.59	4.682	2.053	0.0566
65	27.80	4.742	2.049	.0536
70	28.91	4.796	2.046	.0510
75	29.93	4.846	2.042	.0487
80	30.98	4.893	2.040	.0466
85	31.96	4.936	2.037	.0448
90	32.82	4.977	2.035	.0431
95	33.77	5.015	2.033	.0416
100	34.61	5.052	2.031	.0402
200	47.3	5.521	2.011	0.0258
500	67.4	6.096	1.996	0.0146
1000	85.3	6.502	1.988	0.0097

\* All quantities are believed to be correct to within 3 units in the last place shown. Values for  $n = 2(1)10$  are from Thomson (1953).

\*\* Multipliers for range to get 95% confidence limits of normal population mean.

The following example demonstrates the use of the method. A sample size of twenty-five log values of whip leaf length from the Cedar Hill population of the

Ozark race of *Juniperus virginiana* had a range of 0.637 and a mean of 0.842. It is estimated with 95 per cent confidence that the population mean lies within  $0.842 \pm 0.067$  or 0.775 to 0.909 (5.96 mm. to 8.11 mm.).

## APPENDIX BIBLIOGRAPHY

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